



Biological Assessment and Metals Characterization Report

Center Creek (WBID 3203), Jasper County

Fall 2014 – Fall 2015

Prepared for:
Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

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TABLE OF CONTENTS

Section	Page
1.0 Introduction.....	1
1.1 Justification.....	1
1.2 Objectives	2
1.3 Null Hypotheses.....	2
2.0 Methods.....	3
2.1 Study Timing	3
2.2 Study Area, Station Locations and Descriptions	3
2.2.1 Ecological Drainage Unit.....	4
2.2.2 Land Use Description	7
2.3 Stream Habitat Assessment Project Procedure	7
2.4 Biological Assessment.....	8
2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics.....	8
2.4.2 Macroinvertebrate Analyses: Secondary Metrics	9
2.4.3 General Water Quality Sampling and Analyses	9
2.4.4 Discharge	10
2.5 Surface Water: Dissolved Metals.....	10
2.6 Fine Sediment: Total Metals Characterization	10
2.7 Quality Control	11
3.0 Results.....	11
3.1 Stream Habitat Assessment.....	12
3.2 Biological Assessment.....	12
3.2.1 Macroinvertebrate Community Analyses: Primary Metrics	12
3.2.2 Macroinvertebrate Community Analyses: Secondary Metrics	14
3.2.3 General Water Quality Analyses	16
3.3 Surface Water: Dissolved Metals.....	18
3.4 Fine Sediment Characterization.....	20
3.4.1 Total Metals – 2014	20
3.4.2 Total Metals – 2015	20
4.0 Discussion.....	23
4.1 Stream Habitat Assessment.....	24
4.2 Biological Assessment.....	24
4.2.1 Macroinvertebrate Community Analyses: Primary Metrics	24
4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics	25
4.2.3 General Water Quality	26
4.3 Surface Water: Dissolved Metals.....	28
4.4 Fine Sediment: Total Metals Characterization	29
4.4.1 Remediation Efficacy.....	30
4.4.2 Potential Sediment Pulse.....	31

TABLE OF CONTENTS (cont.)

Section	Page
4.5 Fine Sediment Metals Influence on Surface Water Dissolved Metals.....	32
5.0 Conclusions.....	33
6.0 Recommendations.....	34
7.0 Literature Cited	35

TABLES

	Page
Table 1 Locations and Descriptions of Center Creek, Jones Creek and Mikes Creek Stations 2014-2015.....	4
Table 2 Percent Land Use/Cover for Center Creek Stations (HUC-12) and the Ozark/Neosho EDU.....	7
Table 3 Stream Habitat Assessment Project Procedure (SHAPP) Scores and Comparisons with SHAPP Control Streams	12
Table 4 Center Creek Stations, Fall 2014 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Identify Metric Scores	13
Table 5 Center Creek Stations, Fall 2015 – Individual Metric Values and Scores, Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station; Biological Criteria Scoring Table (bottom in gray) Used to Identify Metric Scores	14
Table 6 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Center Creek Stations, Fall 2014.....	15
Table 7 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and Center Creek Stations, Fall 2015.....	16
Table 8 Physicochemical Water Constituents for Center Creek Stations, Fall 2014	17
Table 9 Physicochemical Water Constituents for Center Creek Stations, Fall 2015	18
Table 10 Surface Water (Grab Sample) Dissolved Metals (µg/L) and Hardness as CaCO ₃ for Center Creek Stations, Fall 2014	19
Table 11 Surface Water (Grab Sample) Dissolved Metals (µg/L) and Hardness as CaCO ₃ for Center Creek Stations, Fall 2015	19
Table 12 Fine Sediment Character, Fall 2014: Total Recoverable Cadmium, Lead, and Zinc Concentrations (mg/kg) at Center Creek Stations	21
Table 13 Fine Sediment Character, Fall 2015: Total Recoverable Cadmium, Lead, and Zinc Concentrations (mg/kg) at Center Creek Stations	22

FIGURES

		Page
Figure 1	Center Creek (3203) in the Ozark/Neosho EDU, Fall 2014 and Fall 2015.....	5
Figure 2	Center Creek (3203) Stations, Jasper County, Fall 2014 and Fall 2015	6
Figure 3	Total Cadmium per Station: 2014 and 2015	22
Figure 4	Total Lead per Station: 2014 and 2015	23
Figure 5	Total Zinc per Station: 2014 and 2015	23
Figure 6	<i>M. mediopunctatum</i> vs. <i>M. pulchellum</i> Average Percent per Station	27
Figure 7	Average Total and Dissolved Zinc per Station	33

ATTACHMENTS

Appendix A	Macroinvertebrate Bench Sheet Report: Center Creek, Jasper County, Missouri Fall 2014 and Fall 2015
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1.0 Introduction

The Center Creek segment included in this study (WBID 3203) is located in the Ozark/Neosho Ecological Drainage Unit in southwestern Missouri (Figure 1). Center Creek is approximately 55 miles long passing through Newton, Lawrence, and Jasper counties before reaching its confluence with Spring River in eastern Kansas. The Center Creek watershed encompasses approximately 300 square miles.

Center Creek is a class P stream, meaning that it maintains permanent flow even during drought periods (MoDNR 2014c). The stream has assigned beneficial use designations that include irrigation (**IRR**), livestock and wildlife watering (**LWW**), protection of aquatic life (**AQL**), human health protection – fish consumption (**HHP**), cool-water fishery (**CLF**), whole-body contact (**WBC**) – category A, secondary contact recreation (**SCR**), and industrial (**IND**) (MoDNR 2014c). Whole body contact category A is defined as:

...waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public. Examples of this category include, but are not limited to: public swimming beaches and property where whole body contact recreational activity is open to and accessible by the public through law or written permission of the landowner (MoDNR 2014c).

1.1 Justification

In Missouri, Center Creek (WBID 3203) flows through part of an area known as the Tri-State Mining District (**TSMD**) in southern Jasper County. This area was one of the greatest producers of lead and zinc for approximately 150 years (Stewart 1986, Allert et al. 2011). Center Creek is on the Clean Water Act Section 303(d) List of Impaired Waters for cadmium and lead in the benthic sediment and cadmium in the surface water (MoDNR 2014a). The Center Creek Total Maximum Daily Load (TMDL) was completed and approved for zinc in 2006 with a priority ranking of “Medium” (MoDNR 2015b). Land adjoining the stream is made up of heavily mined areas that are now included as a United States Environmental Protection Agency (**EPA**) Superfund site (Oronogo/Duenweg Mining Belt, EPA ID: MOD980686281). Remediation efforts by the EPA were in progress during the course of this study. The EPA-approved impaired segment length is 26.8 miles (MoDNR 2014a), all of which is included in this study.

The Center Creek watershed is thought to contribute heavy metals in the water and sediment to Spring River. Allert et al. (2011) found that cadmium, lead, and zinc concentrations were significantly greater at sites downstream from mine waste in Center Creek compared to those sites not adjacent to past mining practices. Metals were elevated in surface water, sediment, detritus, and crayfish tissue.

Heavy metals associated with mine related activity have been found in aquatic organisms. Crayfish and other aquatic macroinvertebrates have accumulated elevated concentrations of metals at mine related streams in Missouri (Besser and Rabeni 1987; Besser et al. 2007; Poulton et al. 2009; Allert et al. 2008, 2009, 2011). Macroinvertebrate communities appear to be negatively affected by mining activities where elevated concentrations of metals are found in

sediment pore water (Besser et al. 2007, 2009a, 2009b; Brumbaugh et al. 2007; Poulton et al. 2009; Allert et al. 2008, 2011).

Urban influences also may affect the ability of Center Creek to meet the protection of aquatic life designated beneficial use. Center Creek flows through and near cities and townships such as Carthage, Carterville, Webb City, Oronogo, and Carl Junction, Missouri.

These potential sources of impairment, or others, may influence the ability of the stream to support the protection of aquatic life beneficial use designation. A stream habitat assessment, biological assessment (which includes benthic macroinvertebrate community and water quality analyses), surface water dissolved metals analyses, and a total metals characterization of benthic fine sediment are included in this study of Center Creek.

This biological assessment and metals characterization study was requested by the MoDNR, Water Protection Program (**WPP**), Water Pollution Control Branch (**WPCB**). The project was conducted by the Division of Environmental Quality (**DEQ**), Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**), and Chemical Analysis Section (**CAS**).

Biological assessments on wadeable/perennial streams conducted by ESP usually take place during a fall and the following spring season. In the study area, Center Creek is a 5th order stream and appears to have been channelized (or contained) as it passes through urban areas. The 300 square mile watershed, larger size, and channelization made using wadeable stream sampling protocols impossible during the normally higher flow in the spring season. For that reason, Center Creek was sampled during the fall of 2014 and fall 2015 when the stream was wadeable.

1.2 Objectives

- Assess the stream habitat quality.
- Assess the “protection of aquatic life” designated beneficial use status using the benthic macroinvertebrate community composition.
- Assess physicochemical water quality.
- Identify the dissolved metals concentrations in the surface water.
- Identify the heavy metals character of the fine sediment in the stream.

1.3 Null Hypotheses

- 1) Stream habitat quality at Center Creek will be comparable to the stream habitat controls.
- 2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Center Creek is fully supporting of the AQL beneficial use, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the 2014 – 2015 fall seasons.

- 3) Dominant macroinvertebrate taxa composition (a secondary biological metric) will indicate that Center Creek macroinvertebrate communities are similar to those of biological criteria reference streams (**BIOREF**) streams.
- 4) Physicochemical water quality constituents will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MoDNR 2014c) and will not be notable when compared to other suggested guidelines.
- 5) Dissolved metals in the surface water will be within acceptable hardness-dependent limits as outlined in Missouri's WQS (MoDNR 2014c).
- 6) Heavy metals (i.e. total cadmium, lead, zinc) concentrations associated with benthic fine sediment will be below threshold levels.

2.0 Methods

Kenneth B. Lister, Brandy Bergthold, Brian Nodine, Raissa Espejo, Rachel Heth, Dave Michaelson, and other ESP personnel were involved in aspects of this study. Methods and study timing are outlined in this section. The study area, station locations and descriptions, EDUs, and land uses are described below. Sample collection and analysis procedures for the stream habitat assessment, biological assessment, surface water dissolved metals, and total metals characterization of the benthic fine sediment are outlined in this section.

2.1 Study Timing

The Missouri Department of Natural Resources (Department) bioassessments usually include samples from a fall season and the following spring season (MoDNR 2012). As mentioned earlier, normal or average spring discharge was too great and subsequently the stream was too deep to apply our wadeable stream protocols that would include sampling in the spring season. Bioassessment, dissolved metals, and fine sediment sampling took place in the fall of 2014 and fall of 2015 when stream discharge was less and the stream was wadeable, or at least had wadeable reaches. Macroinvertebrate and water quality sampling, along with surface water dissolved metals and fine sediment sampling, were conducted on September 16, 2014, at stations #6, #5, and #2. The team sampled stations #4, #3, and #1 on September 17, 2014. The fall 2015 samples were collected on October 6 at stations #6, #5, and #2. On October 7, the team sampled stations #4, #3, and #1. Stream habitat assessments were conducted at Center Creek on September 11, 2014, at stations #6, #5, and #3; September 16 at station #2; and September 17 at stations #4 and #1. Mikes Creek (McDonald County) and Jones Creek (Jasper County) served as stream habitat assessment controls. Mikes Creek habitat was assessed during a previous study on October 8, 2009, and Jones Creek habitat was assessed on September 11, 2014.

2.2 Study Area, Station Locations and Descriptions

The study area is located within the Ozark/Neosho Ecological Drainage Unit (Figure 1). Six stations were sampled for assessment of Center Creek, Jasper County (Table 1; Figure 2). Stations were arranged in the following order: an upstream test/control (#6); one downstream of Grove Creek (#5); one upstream of Bens Branch (#4); one downstream of Bens Branch (#3); one downstream from Oronogo and Webb City, Missouri (#2); and one downstream of Carl Junction,

Missouri (#1). The study area was approximately 27 miles long. The length of each station was approximately 20-times the average width of the reach, which is consistent with the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP; MoDNR 2012)*.

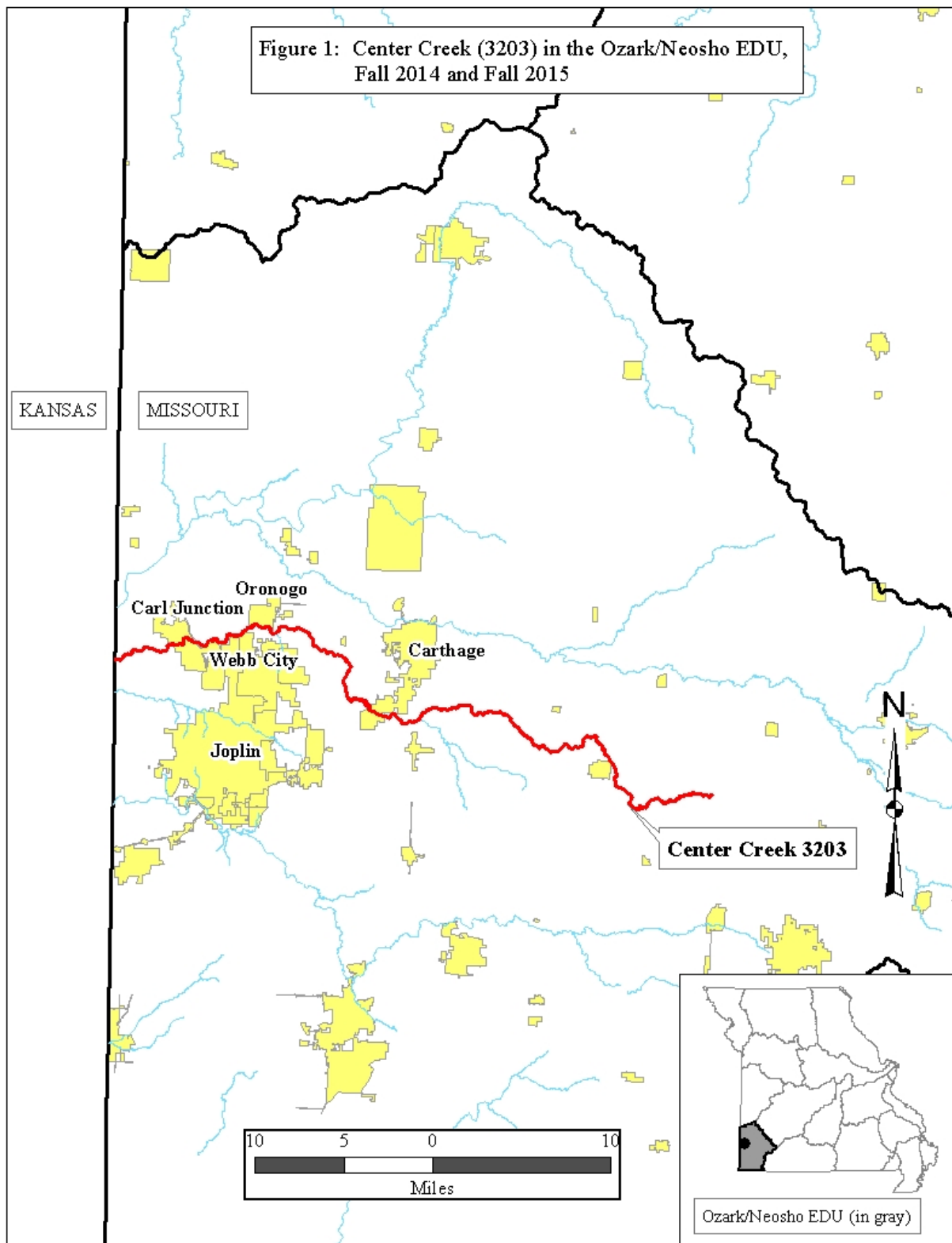
Table 1
Locations and Descriptions of Center Creek, Jones Creek and Mikes Creek Stations 2014-2015

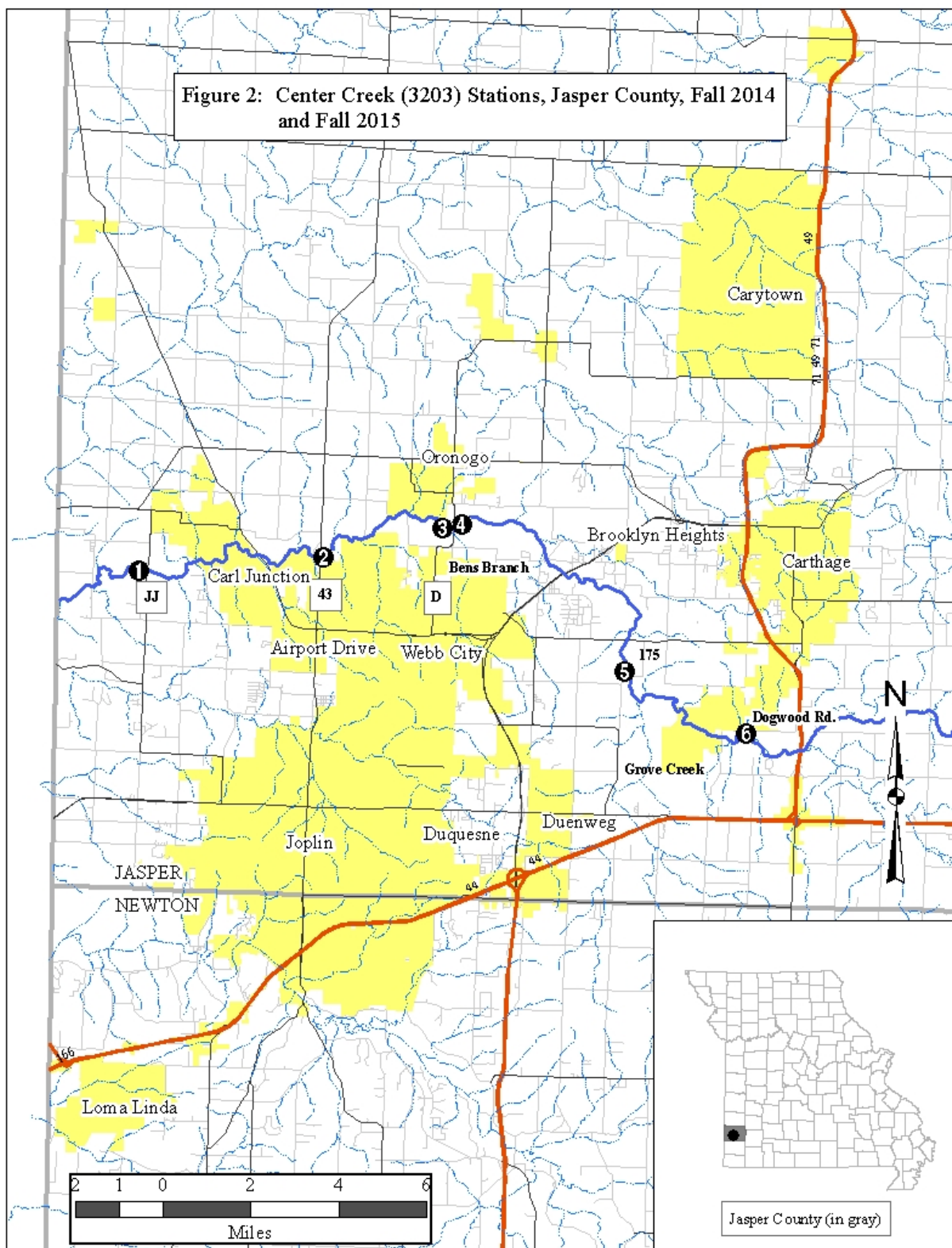
Station	County	Location	Description; WBID	Purpose; Class
Center Creek #6	Jasper	NE¼ sec. 32, T. 28 N., R. 31 W. UTME 381644; UTMN 4107975	South of Dogwood Road	Test/Control; P
Center Creek #5	Jasper	SW¼ sec. 24, T. 28 N., R. 32 W. UTME 377160; UTMN 4110063	Downstream CR 175 bridge	Test; P
Center Creek #4	Jasper	SW¼ sec. 05, T. 28 N., R. 32 W. UTME 370945; UTMN415379	Upstream Hwy. D bridge apx. 50 yards	Test; P
Center Creek #3	Jasper	SE¼ sec. 06, T. 28 N., R. 32 W. UTME 370628; UTMN 4115214	Downstream Hwy. D bridge apx. 150 yards	Test; P
Center Creek #2	Jasper	NE¼ sec. 10, T. 28 N., R. 33 W. UTME365934; UTMN 4114460	Upstream Hwy. 43 Stones Corner CA	Test; P
Center Creek #1	Jasper	SE¼ sec. 12, T. 28 N., R. 34 W. UTME 359658; UTMN 4113966	Downstream Hwy. JJ Carl Junction CA	Test; P
Jones Creek #1	Jasper	SE¼ sec. 13, T. 27 N., R. 31 W. UTME 387294; UTMN 4101514	Downstream Newton Rd. bridge	SHAPP Control; P
Mikes Creek #1 (2009)	McDonald	SE¼ sec.16, T. 22 N., R. 30 W. UTME 394362; UTMN 4054111	Upstream Hwy E bridge Powell, MO.	SHAPP Control; P

CR=County Road; CA= Conservation Area; P=Permanent, SHAPP=Stream Habitat Assessment Project Procedure (MoDNR 2010b).

2.2.1 Ecological Drainage Unit

Center Creek (WBID 3203) is located in the Ozark/Neosho Ecological Drainage Unit (EDU; Figure 1). An EDU is an area that is delineated and identified by its natural terrestrial physiographic division and major riverine watershed components. Ecological Drainage Units are described in detail by Sowa et al. (2007). Streams of similar size within an EDU are expected to contain similar habitat conditions and biological communities. As such, stream habitat, biological, and physicochemical components should be comparable between test streams and reference streams within the same EDU.





2.2.2 Land Use Description

Land uses in close proximity to Center Creek stations were examined (Table 2). Land uses were identified for each station based on the associated 12-digit Hydrological Unit Code (**HUC-12**) area. The percent land use data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**). Land uses were compared by percentage among stations and with the overall EDU. Deviations in land use percentages may identify areas of influence.

Land uses within a stream's watershed should be considered when examining stream habitat assessment and biological assessment results (Table 2). Land use at the upstream station (#6) was generally similar to that of the entire EDU, with grassland and forest being the dominant land uses. Land uses downstream reflected an increase in urbanization and evidence of past mining practices. Impervious, urban, and barren land use percentages increased downstream from station #6 through station #3, as municipal and previously mined areas become more prevalent adjacent to the stream. Grassland, forest, and crops were observed in lower percentages than the EDU in those areas as well. It appears that land cover may influence results of the habitat assessment and biological assessment on Center Creek. The focus of this bioassessment is to identify stream health in the presence of these potential stressors.

Table 2
Percent Land Use/Cover for Center Creek Stations (HUC-12) and the Ozark/Neosho EDU

Stations/Land-Use	#6	#5	#4	#3	#2	#1	Ozark/ Neosho EDU
<i>HUC-12 110702070-</i>	<i>-606</i>	<i>-607</i>	<i>-607</i>	<i>-607</i>	<i>-608</i>	<i>-608</i>	
Impervious	5.0	12.1	12.1	12.1	7.2	7.2	2.6
Urban	1.9	10.2	10.2	10.2	7.0	7.0	2.1
Barren	0.4	2.5	2.5	2.5	0.6	0.6	0.6
Crop	5.1	5.4	5.4	5.4	12.7	12.7	15.2
Grassland	58.8	47.1	47.1	47.1	48.1	48.1	52.8
Forest	22.2	14.5	14.5	14.5	14.5	14.5	20.4
Woody/Herbaceous	4.0	4.4	4.4	4.4	4.8	4.8	4.8
Wetland	2.0	2.4	2.4	2.4	3.7	3.7	1.1
Open-water	0.7	1.3	1.3	1.3	1.6	1.6	0.5

2.3 Stream Habitat Assessment Project Procedure

The standardized *Stream Habitat Assessment Project Procedure* (**SHAPP**) was followed as described for Riffle/Pool prevalent streams (MoDNR 2010b). According to the SHAPP, stream habitat quality is related to the quality of the biological community. Stream habitat quality in control streams (SHAPP control) is compared to the habitat quality of test streams. Habitat metrics are scored, and scores for control stations are compared to those of the test stations. The SHAPP score for each Center Creek station is expressed as a percentage of the mean SHAPP controls. If the SHAPP score at a test station is $\geq 75\%$ of the control scores, the stream habitat at that test station is considered to be comparable to the habitat of the controls. Stream habitat at Mikes Creek (McDonald County) and Jones Creek (Jasper County) served as SHAPP controls for the Ozark/Neosho EDU.

2.4 Biological Assessment

This biological assessment was conducted as described in the SMSBPP (MoDNR 2012). A biological assessment involves examination of the macroinvertebrate community metrics and the physicochemical water results. Primary metrics are numeric descriptions of the macroinvertebrate community structure that ultimately assess the stream's ability to support its beneficial uses. Secondary metrics are used to further illustrate and explain differences in the macroinvertebrate communities that may identify possible sources of influence. Water quality constituents are examined for trends, notable results, and compared to respective water quality standards (MoDNR 2014c) as well as other thresholds if available. Narrative discussions will clarify and integrate results. Biological assessments are grouped by year and station.

2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics

Macroinvertebrate samples were collected from multiple habitats as described in the SMSBPP (MoDNR 2012). Center Creek is considered a riffle/pool dominant stream. As such, coarse substrate (**CS**; riffle), non-flowing water over depositional substrate (**NF**), and rootmat (**RM**) habitats were sampled. In the WQMS laboratory, macroinvertebrates were acquired from subsamples of the benthic material that was collected for each habitat, as described in the SMSBPP (MoDNR 2012). These macroinvertebrates were then identified to specific taxonomic levels (MoDNR 2010c) to provide for consistent and accurate determination of a stream's ability to support the "protection of aquatic life" (AQL) designated beneficial use category. Primary metrics generated from these macroinvertebrate data are used to calculate the MSCI. Ultimately, this MSCI and narrative will assess the test stream's ability to support the designated beneficial use for the protection of aquatic life.

A stream condition index using macroinvertebrates was developed as a measurement of a stream's aquatic biological integrity (Rabeni et al. 1997). The index was further refined to include biological criteria that were generated using wadeable/perennial biological reference streams (**BIOREF**) for each EDU as described in *Biological Criteria for Perennial/Wadeable Streams* (MoDNR 2002). Now called the MSCI, a semi-quantitative rank score is developed by comparing test station metric values to reference criteria, which serve as scoring ranges.

An MSCI score is developed by compiling rank metric scores that are calculated for individual biological metric values. The four primary biological metrics used to calculate the MSCI per station are 1) Taxa Richness (**TR**), 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**), 3) Biotic Index (**BI**), and 4) Shannon Diversity Index (**SDI**). Each metric value for a station is compared to the BIORREF criteria thresholds. The metric then receives a score of 5, 3, or 1 depending on where the metric value falls within the BIORREF scoring range. All four metric scores are then added together to create the MSCI for each station. The MSCI scores are interpreted as follows: 20-16 = fully supporting; 14-10 = partially supporting; and 8-4 = non-supporting of the AQL beneficial use designation. MSCI scores were examined by station and grouped by year.

Individual biological metric values and scores that contribute to the MSCI may be examined. Individual metric values may identify changes in community composition among stations or streams. Individual metric scores are usually evaluated to determine how each metric

contributed to the MSCI score. Variations in certain metric values and scores may aid in identifying types and sources of impairment.

2.4.2 Macroinvertebrate Analyses: Secondary Metrics

Secondary metrics are used to highlight or further analyze findings of the primary metrics and may aid in identifying sources of impairment. One secondary metric, the “Dominant Macroinvertebrate Taxa” (**DMT**) was used to further describe the community composition, as explained in the SMSBPP (MoDNR 2012). This secondary metric was used to compare the similarity of macroinvertebrate community compositions of BIOREF streams (in aggregate) and test streams (MoDNR 2012). If stressors have no effect on the macroinvertebrate community, test stream and BIOREF DMT should be present in similar percentages and taxa rankings should be similar among stations. Differences between BIOREF DMT and test stations or DMT among stations may identify stressors or sources of impairment. Results were arranged by year and station.

A complete taxa list is attached in Appendix A as a bench sheet report, which is grouped by year and station. The bench sheet was used, along with the DMT list, to further examine species occurrence or absence.

2.4.3 General Water Quality Sampling and Analyses

Physicochemical water samples were handled according to the applicable Department, ESP Standard Operating Procedures (**SOPs**) for sampling and analyzing physicochemical water samples. Results for physicochemical water variables were examined by year and station.

Physicochemical water constituents were either recorded from field measurements or analyzed at the ESP environmental laboratory. Water was sampled according to the SOP MoDNR-ESP-001 *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MoDNR 2014b). Temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured *in situ*. The ESP’s CAS in Jefferson City, Missouri, conducted analyses for ammonia as nitrogen (**NH₃-N**; mg/L), nitrate+nitrite as nitrogen (**NO₃+NO₂-N**; mg/L), total nitrogen (**TN**; mg/L), chloride (**Cl**; mg/L), sulfate (**SO₄**; mg/L), total phosphorus (**TP**; mg/L), and non-filterable residue (**NFR**; mg/L). Turbidity (nephelometric turbidity unit, **NTU**) was measured and recorded in the WQMS biology laboratory. All samples that were transported to ESP were kept on ice.

Surface water physicochemical results were compared to acceptable limits and suggested guidelines, or they were highlighted if results were notable among stations. Constituents were compared to Missouri’s Water Quality Standards (MoDNR 2014c). Interpretation of acceptable limits within the WQS may be dependent on a stream’s classification and its beneficial use designation. If no Missouri WQS exist for a constituent, results were compared to applicable suggested guidelines as outlined by the United States Environmental Protection Agency’s (**EPA**) *Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XI* (EPA 2000). The EPA level III ecoregion 39 criteria used for comparison were: **NO₃+NO₂-N** >0.239 mg/L; turbidity >1.425 NTU; **TN** >0.379 mg/L; **TP** >0.006625 mg/L (EPA 2000).

Constituents that were elevated relative to WQS, other thresholds (EPA 2000), or compared to other stations may be highlighted.

2.4.4 Discharge

Stream discharge was measured using a Marsh-McBirney Flowmate 2000™ flow meter at each station. Velocity and depth measurements were recorded at each station and discharge was calculated according to SOP MDNR-ESP-113 *Flow Measurement in Open Channels* (MoDNR 2013b).

2.5 Surface Water: Dissolved Metals

Surface water grab samples were analyzed for dissolved metals content by ESP's CAS. Water grab samples were filtered using a 0.45µm filter, preserved, and handled as outlined in MDNR-ESP-001 (MoDNR 2014b). The dissolved metals included in this project were barium (**Ba**), cadmium (**Cd**), calcium (**Ca**), cobalt (**Co**), copper (**Cu**), lead (**Pb**), magnesium (**Mg**), nickel (**Ni**), and zinc (**Zn**). Iron (**Fe**) and manganese (**Mn**) were included in the 2015 metals analyses. Hardness as CaCO₃ values were calculated using Ca and Mg according to the American Public Health Association (APHA 2012) Standard Methods (2340 B, 2011). Results were compared to hardness dependent chronic and acute toxicity thresholds for heavy metals that are described in Missouri's WQS (MoDNR 2014c). These limits are based on lethality of a toxicant given long-term (chronic toxicity) or short-term (acute toxicity) exposure. Availability of metals concentrations at stations may also identify intermittent or continuous influences, as well as longitudinal trends.

2.6 Fine Sediment: Total Metals Characterization

Instream deposits of benthic fine sediment (i.e. particle size <2 mm) were collected and characterized for total recoverable cadmium, lead, and zinc (mg/kg). The CAS conducted metals character analyses. Notable results are those that exceed or are near threshold concentrations determined by MacDonald et al (2000) for individual metals (PEC, PEQ) or concentrations published in MacDonald et al. (2009) for effects from a mixture or combination of these metals (ΣPEQ and mean PEQ).

Fine sediment was collected from the test stations during each year. A 2-ounce glass jar was used to dredge fine sediment from the substrate no deeper than 2 inches. Three 2-ounce samples were composited into one 8-ounce glass jar. The fine sediment was subsampled from the 8-ounce jar and analyzed for total metals concentrations (µg/kg) by ESP's CAS. Individual total metals concentrations (mg/kg) and mixture or combination of metals quotients were compared to threshold levels.

Individual metals concentrations were compared to Probable Effects Concentrations (**PECs**; MacDonald et al. 2000). A PEC is a threshold level for a contaminant, above which harmful effects are likely to be observed. MacDonald et al. (2000) found PECs to be reliable for 10 metals (including cadmium, lead, and zinc) in classifying sediments as potentially toxic or non-toxic to sediment-dwelling organisms. The PEC for cadmium = 4.98 mg/kg dry weight, lead = 128 mg/kg dry weight, and zinc = 459 mg/kg dry weight (MacDonald et al. 2000).

Individual metals were also examined using a Probable Effects Concentration Quotient (**PEQ**; MacDonald et al. 2000, 2009; Ingersoll et al. 2001, 2002, 2009; Besser et al. 2008, 2009a). A PEQ is the total recoverable metal concentration divided by the PEC for that metal (MacDonald et al. 2000). A PEQ greater than 1.0 may indicate an increased risk of toxicity due to the concentration of that metal (Besser et al. 2009a).

The toxic effects from a mixture or combination of metals may be examined using the sum of PEQs (Σ **PEQ**; Ingersoll et al. 2001; Besser et al. 2009a, 2009b; MacDonald et al. 2000, 2009; Allert et al. 2011) or the **mean PEQ**. For this study, the Σ PEQ is the sum of cadmium, lead, and zinc concentrations. The mean PEQ is the Σ PEQ divided by the number of metals that were included in the mixture ($n=3$), which may normalize the sample result (Long et al. 1998; MacDonald et al. 2000; Ingersoll et al. 1998, 2001, 2002, 2009; Besser et al. 2008, 2009b).

Individual concentrations, Σ PEQs, and mean PEQs may then be compared to site specific threshold levels developed for the Tri-state Mining District (**TSMD**; MacDonald et al. 2009) to further assess the potential risk of toxicity to benthic invertebrates. Individual metals concentrations may be compared to the TSMD specific threshold levels, or T_{10} values. A T_{10} value corresponds to a 10 percent reduction in the control-adjusted survival or biomass of amphipods, midges, or mussels compared to the average response rate for toxicity test organisms exposed to reference sediments. The TSMD threshold (T_{10}) for cadmium is 11.1 mg/kg, lead $T_{10} = 150$ mg/kg, and zinc $T_{10} = 2083$ mg/kg. Both the Σ PEQ and the mean PEQ are included for comparison, although both are individually effective in predicting potential toxicity due to a mixture or combination of metals. The thresholds for a mixture or combination of cadmium, lead, and zinc are Σ PEQ_{Cd, Pb, Zn} = 7.92 and mean PEQ_{Cd, Pb, Zn} = 1.11 (MacDonald et al. 2009). Metals quotients above these thresholds suggest that the mixture or combination of metals associated with the fine sediment is likely to be toxic to the benthic-dwelling macroinvertebrate community.

2.7 Quality Control

Quality control was conducted in accordance with applicable Department SOPs and the SMSBPP (MoDNR 2012). Duplicate macroinvertebrate samples are collected at two randomly selected stations among all project streams during each sample season. Duplicate samples are compared using the Quality Similarity Index (**QSI**), which is used to assess the consistency between sample collector techniques as well as the accuracy of taxonomic identification. No duplicate samples were collected from Center Creek. Duplicate surface water and fine sediment samples were collected and analyzed for every 10 samples to assess precision of collection and analyses.

3.0 Results

Results from stream habitat assessments, biological assessments, surface water dissolved metals, and total metals character of the benthic fine sediments are presented in this section. Notable results or trends are highlighted for each section. Results are grouped by year and station.

3.1 Stream Habitat Assessment

Stream habitat quality was assessed using SHAPP scores for each station. Scores for each station were compared to the average of the SHAPP control scores to develop a percent similarity with the controls (Table 3). Station #6 (upstream) scored 96 percent similarity to the SHAPP controls. Stations #5 and #4 scores dropped slightly to 84 and 88 percent, respectively. Station #3 achieved a 100 percent similarity to SHAPP controls. Scores lowered slightly from 97 to 87 percent similarity at stations #2 and #1, respectively. Overall, stream habitat in Center Creek stations was considered to be comparable to the SHAPP controls. Based on habitat scores, Center Creek should be capable of supporting a macroinvertebrate community similar to the control streams.

Table 3
Stream Habitat Assessment Project Procedure (SHAPP) Scores and
Comparisons with SHAPP Control Streams

Station	SHAPP Score	Percent Similarity
Center Creek #6	143	96
Center Creek #5	126	84
Center Creek #4	132	88
Center Creek #3	150	100
Center Creek #2	144	97
Center Creek #1	130	87
Jones Creek #1	150	Mean of Controls
Mikes Creek #1 (2009)	148	

3.2 Biological Assessment

Biological assessments consist of macroinvertebrate community primary and secondary metric analyses, as well as general water quality analyses. Notable results for Center Creek are grouped by year.

3.2.1 Macroinvertebrate Community Analyses: Primary Metrics

In 2014, Center Creek MSCI scores generally decreased from upstream to downstream (Table 4). Stations #6, #5, and #4 received the optimum MSCI score (20) and were considered fully supporting of the AQL. Station #3, immediately downstream from the confluence with Bens Branch, decreased slightly (18), yet maintained full support of the AQL. The MSCI at station #2 (14) dropped substantially, and subsequently the station was considered to be partially supporting of the AQL. The MSCI increased to a fully supporting score of 16 at station #1.

Several individual metric values contributed to the less than optimum metric scores that ultimately affected the MSCI scores in 2014 (Table 4). At station #3, the BI value (5.8) was slightly higher than the optimum criteria threshold (<5.5), which contributed to the less than optimum MSCI score. Three metric values at station #2 contributed to partial support designation. The TR metric value (75) was less than optimum and as many as 21 fewer than upstream stations. The EPTT value (14) was 11 taxa below the optimum scoring threshold and as few as half of the upstream stations. And finally, the BI of station #2 (5.7) was slightly higher

than the optimum criteria (<5.5). Two metric values influenced the MSCI at station #1 in 2014. The EPTT value (13) was 19 taxa lower than the optimum range, and less than half of upstream stations. The BI metric value (6.3) at station #1 was the highest of all stations.

Table 4
Center Creek Stations, Fall 2014 – Individual Metric Values and Scores,
Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station;
Biological Criteria Scoring Table (bottom in gray) Used to Identify Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Center Creek #6	14900	96 ₍₅₎	31 ₍₅₎	4.8 ₍₅₎	3.76 ₍₅₎	20	F
Center Creek #5	14901	90 ₍₅₎	28 ₍₅₎	5.3 ₍₅₎	3.62 ₍₅₎	20	F
Center Creek #4	14904	94 ₍₅₎	29 ₍₅₎	5.4 ₍₅₎	3.55 ₍₅₎	20	F
Center Creek #3	14903	92 ₍₅₎	28 ₍₅₎	5.8₍₃₎	3.16 ₍₅₎	18	F
Center Creek #2	14902	75₍₃₎	14₍₃₎	5.7₍₃₎	3.10 ₍₅₎	14	P
Center Creek #1	14905	81 ₍₅₎	13₍₃₎	6.3₍₃₎	3.10 ₍₅₎	16	F
Metric Score=5	↔	>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3	↔	77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1	↔	<39	<12	>7.7	<1.49	8-4	Non

BIOREF Scoring Table (bottom) developed from BIORREF streams ($n = 10$); TR = Taxa Richness; EPTT = Ephemeroptera, Plecoptera, Trichoptera Taxa; BI = Biotic Index; SDI = Shannon Diversity Index; (#subscript) = Individual metric score; **Bold** = less than optimum value and score.

In 2015, MSCI scores also decreased from upstream to downstream (Table 5). Stations #6, #5, and #4 attained optimum MSCI scores of 20, and subsequently all were fully supporting of the AQL. Station #3, upstream of Bens Branch, attained a slightly lower score of 18, but maintained its fully supporting status. The MSCI at station #2 (14) decreased substantially and was again considered partially supporting of the AQL. The MSCI at Station #1 (14) categorized the station as partially supporting of the AQL in 2015.

Less than optimum metric values affected MSCI scores in 2015 (Table 5). At station #3, the BI metric value (5.7) was again slightly above the criteria (<5.5), which contributed to a less than optimum MSCI score. Three metric values contributed to the partially supporting MSCI score at station #2. The TR (67) had 11 fewer taxa than the optimum range, and as many as 27 fewer taxa than upstream. The EPTT value (15) had nine fewer EPTT than the optimum range, and as few as half of that found in upstream stations. The BI (5.7) was slightly higher than the optimum criteria (<5.5) at station #2. The same three metrics contributed to a partially supporting MSCI

score at station #1. The TR (67) contained 11 fewer taxa than the optimum criteria (>77); the EPTT value (18) had nine fewer taxa than the optimum range (>24); and the BI (5.7) was slightly higher than the optimum (<5.5).

Table 5
Center Creek Stations, Fall 2015 – Individual Metric Values and Scores,
Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station;
Biological Criteria Scoring Table (bottom in gray) Used to Identify Metric Scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Center Creek #6	15050	94 ₍₅₎	30 ₍₅₎	5.1 ₍₅₎	3.72 ₍₅₎	20	F
Center Creek #5	15051	92 ₍₅₎	28 ₍₅₎	5.2 ₍₅₎	3.71 ₍₅₎	20	F
Center Creek #4	15054	90 ₍₅₎	27 ₍₅₎	5.3 ₍₅₎	3.57 ₍₅₎	20	F
Center Creek #3	15053	86 ₍₅₎	28 ₍₅₎	5.7₍₃₎	3.43 ₍₅₎	18	F
Center Creek #2	15052	67₍₃₎	15₍₃₎	5.6₍₃₎	3.01 ₍₅₎	14	P
Center Creek #1	15055	67₍₃₎	18₍₃₎	5.7₍₃₎	3.14 ₍₅₎	14	P
Metric Score=5	↔	>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3	↔	77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1	↔	<39	<12	>7.7	<1.49	8-4	Non

BIOREF Scoring Table (bottom) developed from BIORREF streams ($n = 10$); TR = Taxa Richness; EPTT = Ephemeroptera, Plecoptera, Trichoptera Taxa; BI = Biotic Index; SDI = Shannon Diversity Index; (#subscript) = Individual metric score; **Bold** = less than optimum value and score.

3.2.2 Macroinvertebrate Community Analyses: Secondary Metrics

The dominant macroinvertebrate taxa (DMT) metric was used to examine the community composition of Center Creek stations. The top 10 DMT at BIORREF streams were compared to the DMT list for Center Creek 2014 and 2015 samples. Each DMT's abundance and rank was compared to the respective abundance and rank in Center Creek stations for 2014 and 2015.

Two taxa, *Paraleptophlebia* sp. and *Marilia* sp., were absent or were much less abundant in all Center Creek stations, so their absence will be minimized when examining for trends. Stations that are missing BIORREF DMT and those where these taxa are much less abundant will be highlighted. Results of the DMT analysis are arranged by year and notable station.

In 2014 two stations exhibited interesting results (Table 6). Seven of the 10 BIORREF DMT were either absent from station #2, or they were much less abundant than upstream stations. Five of the 10 BIORREF DMT, *Paraleptophlebia* sp., *Baetis* sp., *Marilia* sp., *Caenis latipennis*, and

Optioservus sandersoni, were absent at station #2, and two additional taxa, *Psephenus herricki* and *Stenelmis* sp., were much less abundant than at upstream stations in Center Creek. At station #1, 6 of the 10 BIOREF DMT were absent or much less abundant than other upstream stations. *P. herricki*, *Paraleptophlebia* sp., *Baetis* sp., *Marilia* sp., and *C. latipennis* were absent, whereas two taxa, *P. herricki* and *O. sandersoni*, were much less abundant than upstream stations.

Table 6
Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and
Center Creek Stations, Fall 2014

Dominant Taxa	BIOREF	#6	#5	#4	#3	#2	#1
<i>Psephenus herricki</i>	15.94 (1)	6.08 (2)	2.28 (14)	0.34 (45)	0.53 (29)	0.08 (64)	--
<i>Hyalella azteca</i>	8.22 (2)	0.24 (50)	4.70 (7)	3.23 (6)	9.51 (2)	5.24 (5)	4.04 (5)
<i>Cheumatopsyche</i>	4.83 (3)	1.52 (18)	1.07 (22)	0.13 (66)	--	3.91 (7)	1.99 (12)
<i>Paraleptophlebia</i>	4.63 (4)	--	--	--	--	--	--
<i>Baetis</i>	3.16 (5)	3.92 (7)	0.71 (31)	1.88 (14)	0.60 (25)	--	--
<i>Marilia</i>	3.15 (6)	--	0.07 (72)	--	--	--	--
<i>Caenis latipennis</i>	3.13 (7)	3.20 (12)	3.85 (9)	0.54 (36)	1.13 (17)	--	6.24 (2)
<i>Lirceus</i>	3.11 (8)	0.08 (83)	0.21 (59)	0.27 (52)	0.27 (46)	0.16 (48)	0.55 (31)
<i>Stenelmis</i>	3.07 (9)	4.80 (5)	7.62 (2)	12.52 (1)	5.59 (3)	0.08 (65)	1.17 (21)
<i>Optioservus sandersoni</i>	2.85 (10)	0.24 (51)	0.43 (42)	0.40 (42)	0.60 (26)	--	0.07 (73)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = notable percentage or rank.

In 2015 the dominant taxa at two stations were substantially different from BIOREF DMT (Table 7). Eight of the 10 BIOREF DMT were either absent from station #2 or were much less abundant than other upstream stations (Table 7). Four BIOREF DMT, *Paraleptophlebia* sp., *Marilia* sp., *C. latipennis*, and *Lirceus* sp., were absent, and four taxa, *P. herricki*, *Baetis* sp., *Stenelmis* sp., and *O. sandersoni*, were much less abundant than other upstream stations in Center Creek. In 2015, six of the ten BIOREF DMT were absent from station #1 or greatly reduced in percentage relative to other upstream stations (Table 7). Three BIOREF DMT were absent, *Paraleptophlebia* sp., *Marilia* sp., and *O. sandersoni*, whereas three additional taxa, *P. herricki*, *Baetis* sp., and *Stenelmis* sp., were much less abundant than were found in other upstream stations in Center Creek.

Table 7
Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and
Center Creek Stations, Fall 2015

Dominant Taxa	BIOREF	#6	#5	#4	#3	#2	#1
<i>Psephenus herricki</i>	15.94 (1)	2.30 (14)	0.92 (14)	0.32 (42)	0.39 (35)	0.06 (56)	0.07 (57)
<i>Hyalella azteca</i>	8.22 (2)	0.75 (33)	1.34 (21)	0.08 (71)	12.27 (1)	1.26 (15)	5.98 (4)
<i>Cheumatopsyche</i>	4.83 (3)	4.13 (8)	4.59 (6)	1.84 (15)	4.63 (7)	14.82 (1)	11.05 (2)
<i>Paraleptophlebia</i>	4.63 (4)	3.32 (9)	1.06 (23)	--	--	--	--
<i>Baetis</i>	3.16 (5)	2.17 (16)	2.75 (12)	2.25 (13)	1.93 (15)	0.34 (30)	0.21 (35)
<i>Marilia</i>	3.15 (6)	0.07 (75)	--	--	--	--	--
<i>Caenis latipennis</i>	3.13 (7)	--	0.35 (47)	2.41 (12)	0.85 (23)	--	2.22 (13)
<i>Lirceus</i>	3.11 (8)	--	--	0.32 (43)	0.08 (71)	--	0.28 (30)
<i>Stenelmis</i>	3.07 (9)	6.50 (1)	7.42 (2)	12.75 (1)	5.63 (4)	0.52 (24)	0.42 (26)
<i>Optioservus sandersoni</i>	2.85 (10)	0.54 (38)	2.26 (15)	0.56 (36)	0.46 (33)	0.11 (45)	--

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = notable percentage or rank.

The Macroinvertebrate Bench Sheet Report (Appendix A) further documented interesting trends in the number of and family differences in Ephemeroptera (mayfly) taxa from upstream to downstream stations in 2014. Upstream stations #6, #5, #4, and #3 contained between 19 and 21 Ephemeroptera taxa, five to eight of those being Heptageniidae. Stations #2 and #1 each contained five Ephemeroptera taxa and had only a single heptageniid mayfly family. A similar trend was observed in 2015. Upstream stations #6, #5, #4, and #3 contained between 17 and 20 Ephemeroptera taxa, five to seven of those being Heptageniidae. Stations #2 and #1 contained four and eight Ephemeroptera taxa with one and three heptageniids, respectively.

3.2.3 General Water Quality Analyses

General physicochemical water quality constituents for Center Creek stations were examined in 2014 and 2015 (Tables 8 and 9). Constituents were compared to WQS (MoDNR 2014c) and EPA suggested guidelines (EPA 2000), and examined for trends among stations. Results are grouped by year and station.

All constituents were within WQS (MoDNR 2014c) in all stations in 2014 (Table 8). However, turbidity, total nitrogen, nitrate+nitrite as N, and total phosphorus exceeded EPA suggested guidelines (EPA 2000) at all stations. Concentrations of each parameter were relatively similar at all stations with the exceptions of elevated total nitrogen, nitrate+nitrite as N, and total

phosphorus at stations #2 and #1. Conductivity was also higher at station #2 (415 $\mu\text{S}/\text{cm}$) and station #1 (421 $\mu\text{S}/\text{cm}$) compared to upstream stations. Sulfate was as much as approximately seven-times higher at station #2 (33.5 mg/L) and station #1 (35.3 mg/L) than upstream stations. Chloride was also slightly higher at station #2 (12.9 mg/L) and station #1 (14.7 mg/L) compared to upstream stations in 2014.

Table 8
Physicochemical Water Constituents for Center Creek Stations, Fall 2014

Station/Date Parameter	#6	#5	#4	#3	#2	#1
Sample Number	1411906	1411907	1411910	1411909	1411908	1411911
pH (Units)	7.8	8.0	8.0	7.9	7.9	8.2
Temperature ($^{\circ}\text{C}$)	20.0	20.0	20.0	21.0	21.0	23.0
Conductivity ($\mu\text{S}/\text{cm}$)	363	358	357	359	415	421
Dissolved O_2	7.28	8.58	7.15	7.30	8.28	9.77
Discharge (cfs)	28.3	30.1	29.7	28.7	32.2	36.7
NFR	10.0	11.0	13.0	15.0	11.0	8.00
Turbidity (NTUs)	8.57	10.1	12.9	12.4	8.90	9.41
Total Nitrogen	2.59	2.21	2.29	2.36	3.63	3.91
Nitrate+Nitrite as N	2.28 ₀₉	1.94	2.07 ₀₉	1.98	3.28 ₀₉	3.72 ₀₉
Ammonia-N	0.070	0.058	0.033 ₀₅	0.082	0.075	0.079
Sulfate	6.19	4.55 ₀₅	8.21	7.79	33.5	35.3
Chloride	9.78	9.63	10.3	10.8	12.9	14.7
Total Phosphorus	0.062	0.077	0.076	0.077	0.25	0.27

Units mg/L unless otherwise labeled; **Highlighted** = Notable; *Italics* = exceeding EPA (2000) suggested guidelines criteria used for comparison: $\text{NO}_3+\text{NO}_2\text{-N} > 0.239$ mg/L; Turbidity > 1.425 NTU; TN > 0.379 mg/L; TP > 0.006625 mg/L. Subscript qualifiers: 05 = estimated value, detected below the Practical Quantitation Limit (PQL); 09 = sample diluted during analysis.

General physicochemical water quality constituents were examined for Center Creek stations in 2015 (Table 9). All constituents were within WQS guidelines (MoDNR 2014c) in all stations. However, turbidity, total nitrogen, nitrate+nitrite as N, and total phosphorus exceeded EPA suggested guidelines (EPA 2000) at all stations. Constituent concentrations were relatively similar among stations from upstream to downstream, with two exceptions. Sulfate concentrations at station #2 (25.0 mg/L) and station #1 (29.5 mg/L) were as much as two-times higher than upstream stations in the fall of 2015. The total phosphorus concentration at station #1 (0.12 mg/L) was approximately twice as high as the remaining upstream stations.

Table 9
Physicochemical Water Constituents for Center Creek Stations, Fall 2015

Station/Date Parameter	#6	#5	#4	#3	#2	#1
Sample Number	154114	154115	154118	154117	154116	154119
pH (Units)	8.2	8.3	8.1	7.9	8.3	8.3
Temperature (°C)	16.0	16.7	17.4	16.8	17.7	19.4
Conductivity (µS/cm)	338	334	340	363	367	376
Dissolved O ₂	9.42	11.04	8.73	8.44	9.96	10.27
Discharge (cfs)	58.4	68.1	63.8	77.0	80.3	78.3
NFR	<5	<5	6.00	5.00	<5	<5
Turbidity (NTUs)	3.3	2.9	5.8	4.4	3.1	3.5
Total Nitrogen	3.74	3.57	3.38	3.31	3.02	3.45
Nitrate+Nitrite as N	3.54 ₀₉	3.22 ₀₉	3.05 ₀₉	3.00 ₀₉	2.85 ₀₉	3.23 ₀₉
Ammonia-N	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Sulfate	7.96	9.71	10.9	14.6	25.0	29.5
Chloride	10.3	9.81	10.8	10.8	9.71	11.5
Total Phosphorus	0.044 ₀₅	0.053	0.056	0.056	0.057	0.12

Units mg/L unless otherwise labeled; **Highlighted** = notable; *Italics* = exceeding EPA (2000) suggested guidelines criteria used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. Subscript qualifiers: 05 = estimated value, detected below PQL; 09 = sample diluted during analysis.

3.3 Surface Water: Dissolved Metals

Surface water was analyzed for dissolved metals concentrations at all stations in both years (Tables 10 and 11). Notable results are those concentrations that were elevated among stations, as well as concentrations that exceed individual hardness dependent WQSs (MoDNR 2014c). Results are grouped by year, metal, and station.

Three dissolved metals were notable at several stations in fall 2014 (Table 10). Dissolved cadmium was detected (0.14 µg/L) in the surface water of station #2, which was approximately one-third of the chronic toxicity listed in the WQS. The hardness dependent chronic concentration for cadmium is 0.39 µg/L at 195 mg/L hardness as CaCO₃ (MoDNR 2014c). Dissolved lead was detected (1.41 µg/L) at station #2 in 2014, but it did not exceed the chronic toxicity WQS (5.17 µg/L at hardness 195 mg/L as CaCO₃). Dissolved zinc concentrations were similar at stations #6 (2.01 µg/L) and #5 (2.59 µg/L). However, dissolved zinc increased by nearly six-times from station #5 (2.59 µg/L) to station #4 (15.0 µg/L). The concentration then increased by approximately 50 percent from station #4 to station #3 (22.8 µg/L). At station #2, the concentration of dissolved zinc (163 µg/L) increased again by approximately six-times to near the acute and chronic toxicity levels (206 µg/L at hardness 195 mg/L as CaCO₃). The zinc concentration was lower at station #1 (52.4 µg/L) than station #2.

Three dissolved metals were also notable at several stations in 2015 (Table 11). Dissolved cadmium was detected at stations #3, #2, and #1 in 2015. Cadmium was detected at station #3 (0.14 µg/L), reached its highest observed concentration at station #2 (0.46 µg/L), and decreased slightly at station #1 (0.33 µg/L). The dissolved cadmium concentration at station #2 exceeded

the chronic toxicity concentration (0.37 µg/L at 182 mg/L hardness as CaCO₃) in Missouri WQSs (MoDNR 2014c). Dissolved lead was not detected in surface water samples of Center Creek stations in 2015. Dissolved zinc had a nearly five-fold increase from station #5 (3.09 µg/L) to station #4 (15.3 µg/L). The concentration then increased by approximately 50 percent at station #3 (22.8 µg/L). Dissolved zinc increased by approximately seven-times at station #2 (154 µg/L) to near the acute and chronic toxicity levels (195 µg/L at 182 mg/L hardness as CaCO₃) concentrations outlined in the WQS (MoDNR 2014c). Dissolved zinc then decreased slightly from station #2 to station #1(117 µg/L).

Table 10
Surface Water (Grab Sample) Dissolved Metals (µg/L) and Hardness as CaCO₃
for Center Creek Stations, Fall 2014

Station/ Sample No.	#6 1411906	#5 1411907	#4 1411910	#3 1411909	#2 1411908	#1 1411911
Barium	73.8	73.8	76.8	77.9	73.2	75.4
Cadmium	<0.10	<0.10	<0.10	<0.10	0.14 ₀₅	<0.10
Cobalt	<1	<1	<1	<1	<1	<1
Copper	<0.50	0.61 ₀₅	0.66 ₀₅	0.72 ₀₅	0.79 ₀₅	0.98 ₀₅
Lead	<0.50	<0.50	<0.50	<0.50	1.41	0.85 ₀₅
Nickel	0.84 ₀₅	0.88 ₀₅	1.00	0.94 ₀₅	2.04	1.96
Zinc	2.01	2.59	15.0	22.8	163	52.4
Calcium (mg/L)	62.7	63.3	63.0	63.2	71.2	70.7
Magnesium (mg/L)	3.68	3.62	3.64	3.61	4.28	4.46
Hardness (Dissolved)(mg/L)	172	173	172	173	195	195

Units µg/L unless otherwise labeled; Highlight = Notable; Subscript qualifier: 05 = Estimated value, detected below PQL.

Table 11
Surface Water (Grab Sample) Dissolved Metals (µg/L) and Hardness as CaCO₃
for Center Creek Stations, Fall 2015

Station/ Sample No.	#6 154114	#5 154115	#4 154118	#3 154117	#2 154116	#1 154119
Barium	72.6	72.2	72.8	75.9	71.8	73.0
Cadmium	<0.10	<0.10	<0.10	0.14 ₀₅	0.46 _c	0.33
Cobalt	<1	<1	<1	<1	<1	<1
Copper	<0.50	<0.50	0.62 ₀₅	<0.50	<0.50	0.94 ₀₅
Iron (2015 only)	7.59	6.22	9.78	8.95	9.64	5.87
Lead	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Manganese (2015 only)	6.28	5.17	8.66	7.46	57.3	21.5
Nickel	<0.50	<0.50	<0.50	<0.50	<0.50	1.07
Zinc	1.83	3.09	15.3	22.8	154	117
Calcium (mg/L)	60.8	62.4	62.7	63.0	66.8	67.6
Magnesium (mg/L)	3.72	3.74	3.69	3.69	3.71	4.03
Hardness (Dissolved)(mg/L)	167	171	172	173	182	185

Units µg/L unless otherwise labeled; Bold = outside WQS acceptable range, c = chronic toxicity (MoDNR 2014c); Highlight = Notable; Subscript qualifier: 05 =Estimated value, detected below PQL.

3.4 Fine Sediment Characterization

Benthic fine sediment (<2.0 mm) was characterized for total cadmium, lead, and zinc concentrations in 2014 and 2015 (Tables 12 and 13; Figures 3, 4, and 5). Notable results are those that were near or exceeded threshold concentrations for individual metals (PEC, PEQ), as identified by MacDonald et al. (2000), or those that exceeded Tri-state Mining District (TSMD) site specific criteria (MacDonald et al. 2009). The mixture or combination of metals quotients (Σ PEQ and mean PEQ) were also compared to MacDonald et al. (2009) thresholds.

3.4.1 Total Metals – 2014

Total cadmium concentrations in fine sediment samples were notable in several Center Creek stations in 2014 (Table 12; Figure 3). Total cadmium concentrations were well below the PEC at stations #6 and #5; however, there was a slight increase at station #5. Cadmium at station #4 (4.190 mg/kg) increased to a concentration near the PEC threshold (4.98 mg/kg). The cadmium concentration increased by nearly 10-times at station #3 (46.6 mg/kg), which was well above the PEC. The cadmium concentration nearly doubled again from station #3 to #2 (72.1 mg/kg) and exceeded the PEC threshold by over 14-times. Cadmium decreased by approximately one-third from station #2 to station #1 (26.8 mg/kg); however, the concentration remained above the PEC threshold. Cadmium concentrations also exceeded the TSMD site specific criterion (T_{10}) of 11.1 mg/kg at stations #3, #2 and #1.

Total lead concentrations in the fine sediment of Center Creek stations also were notable in 2014 (Table 12; Figure 4). Lead concentrations at stations #6 and #5 were well below the PEC; however, there was a slight increase at station #5. The station #4 lead concentration (119 mg/kg) was near, but did not exceed the PEC (128 mg/kg). Lead concentrations increased at station #3 (233 mg/kg), reached a longitudinal high at station #2 (571 mg/kg), and decreased slightly at station #1 (292 mg/kg). All three stations exceeded the PEC threshold. Lead concentrations also exceeded the TSMD site specific criterion (T_{10}) of 150 mg/kg at stations #3, #2, #1.

The total zinc concentrations in the fine sediment at stations #6 and #5 were below the PEC threshold (459 mg/kg) in 2014; however, there was a slight increase at #5 (Table 12; Figure 5). Total zinc exceeded the PEC at stations #4 (930 mg/kg), #3 (9520 mg/kg), #2 (11,200 mg/kg), and #1 (4110 mg/kg). Total zinc concentrations exceeded the TSMD (T_{10}) site specific criterion of 2083 mg/kg at stations #3, #2, and #1.

In 2014, the mixture or combination of metals thresholds (Σ PEQ or mean PEQ) were exceeded at several stations (Table 12). Exceedance of the Σ PEQ threshold (≥ 7.92) indicated that a mixture of metals may have a toxic effect on macroinvertebrate community at stations #3 (31.86), #2 (262.98), and #1 (16.58). The mean PEQ suggested that stations #4, #3, #2, and #1 all had the potential of toxic effects due to a mixture or combination of cadmium, lead, and zinc in the fine sediment.

3.4.2 Total Metals – 2015

In 2015, total cadmium concentrations followed a trend that was similar to 2014 (Table 13; Figure 3). Cadmium concentrations again were well below PEC threshold levels at stations #6 and #5; however, the concentration increased slightly at station #5. Station #4 cadmium

(5.61 mg/kg) exceeded the PEC threshold (4.98 mg/kg). Stations #3 and #2 had the highest concentrations (13.5 mg/kg and 11.4 mg/kg, respectively) of all stations, exceeding the cadmium PEC by as much as 2.7-fold. Cadmium decreased slightly at station #1 (8.94 mg/kg), but it was still nearly twice that of the PEC threshold. Cadmium concentrations exceeded the site specific criterion of 11.1 mg/kg for the TSMD at stations #3 and #2; however, concentrations at stations #4 and #1 did not.

Total lead associated with fine sediment was observed at several stations in 2015 (Table 13, Figure 4). Lead concentrations at stations #6 and #5 did not exceed the PEC in 2015; however, there was a slight increase at station #5. The concentration of lead at station #4 (110 mg/kg) was near but did not exceed the PEC (128 mg/kg). Total lead at station #3 (102 mg/kg) and #1 (117 mg/kg) were also near but did not exceed the PEC threshold. The total lead concentration at station #2 (167 mg/kg) exceeded the PEC threshold (128 mg/kg) in 2015. The lead concentration exceeded TSMD site specific criterion of 150 mg/kg at station #2.

In 2015, the total zinc concentrations in the fine sediment were below the PEC threshold (459 mg/kg) at stations #6 and #5; however, there was a slight increase at station #5 (Table 13; Figure 5). Total zinc exceeded the PEC threshold at stations #4 (984 mg/kg), #3 (2540 mg/kg), #2 (2960 mg/kg), and #1 (1570 mg/kg). Zinc concentrations at station #4 did not exceed the TSMD T₁₀ (2083 mg/kg); however, stations #3, and #2 were also above the site specific criterion.

In 2015, the mixture or combination of metals thresholds (Σ PEQ or mean PEQ) were exceeded at several stations (Table 13). Exceedance of the Σ PEQ threshold (≥ 7.92) identified potential toxic effects from a mixture of metals at stations #3 (9.04), #2 (10.04), while #1 (6.13) was near the sum threshold. The mean PEQ also suggested that the composition of macroinvertebrate communities at stations #4, #3, #2, and #1 all were potentially influenced by a toxic mixture or combination of heavy metals associated with the fine sediment.

Table 12
Fine Sediment Character, Fall 2014: Total Recoverable Cadmium, Lead, and Zinc
Concentrations (mg/kg) at Center Creek Stations

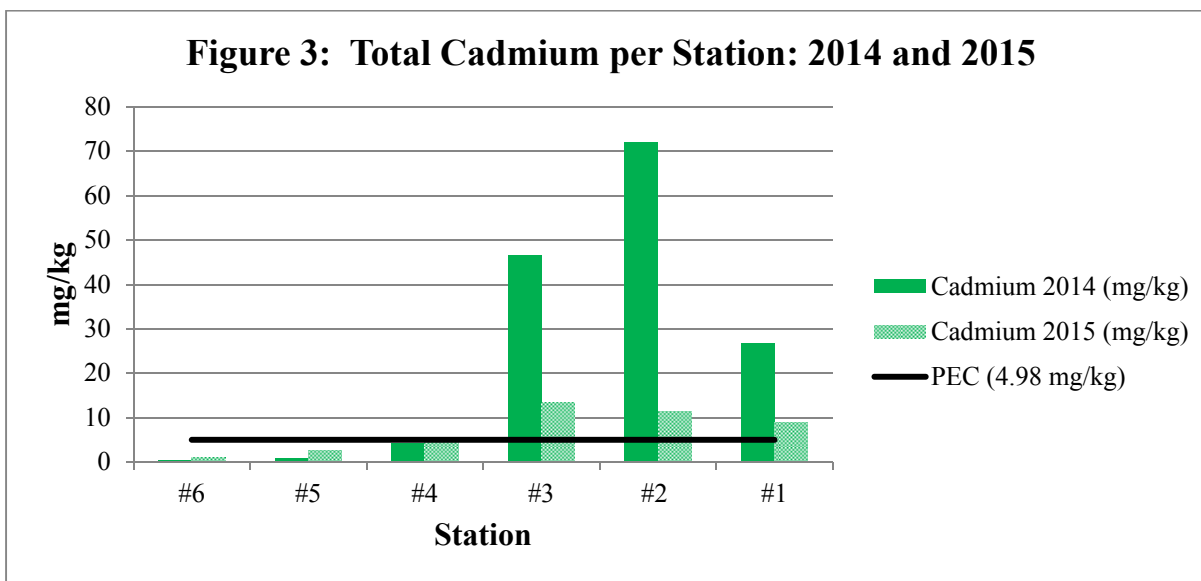
Station/ Sample No.	#6 1411885	#5 1411886	#4 1411889	#3 1411888	#2 1411887	#1 1411890	PEC Threshold	PEQ Threshold
Cadmium (PEQ)	0.428 ₀₅ (0.086)	0.737 (0.148)	4.190 (0.841)	46.600 (9.357)	72.100 ₁₁ (14.478)	26.800 (5.381)	4.98	>1.0
Lead (PEQ)	12.0 (0.1)	23.9 (0.2)	119.0 (0.9)	233.0 ₀₉ (1.8)	571.0 ₀₉ (4.5)	292.0 (2.3)	128.0	>1.0
Zinc (PEQ)	87.5 (0.2)	153.0 (0.3)	930.0 ₀₉ (2.0)	9520.0 ₀₉ (20.7)	11200.0 ₀₉ (244.0)	4110.0 ₀₉ (8.9)	459.0	>1.0
Σ PEQ	0.386	0.648	3.741	31.857	262.978	16.581	--	≥ 7.92
Mean PEQ	0.129	0.216	1.247	10.619	16.581	5.527	--	≥ 1.11

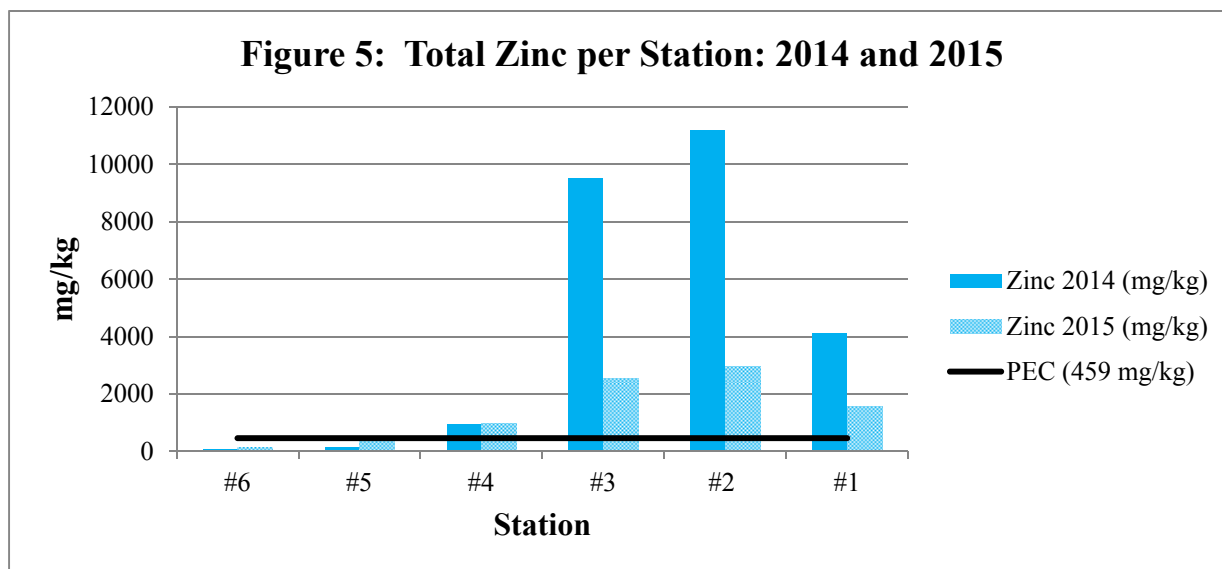
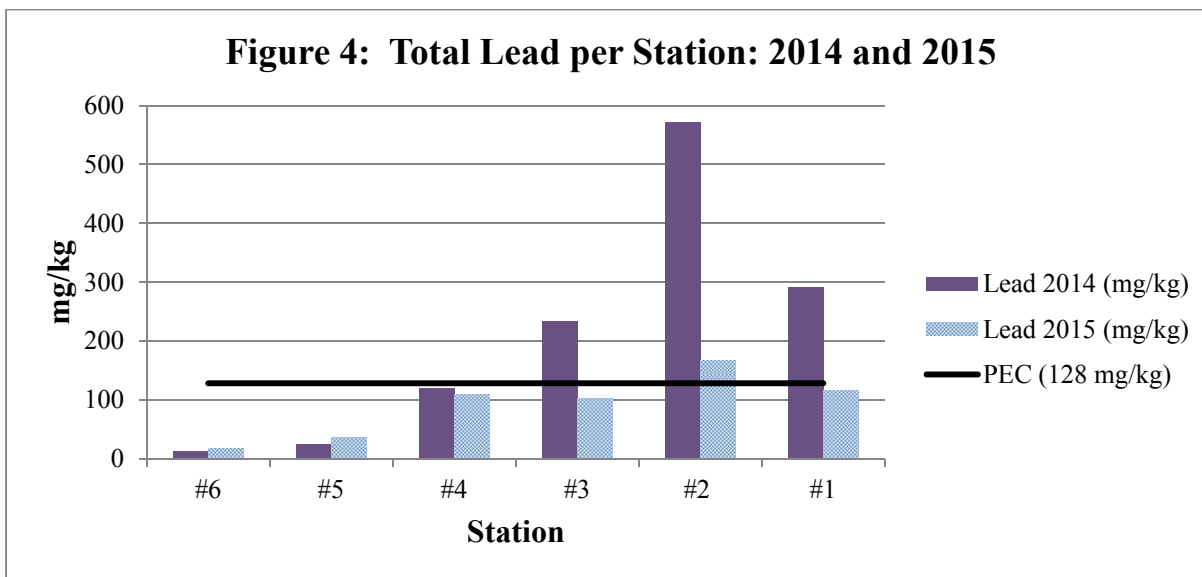
PEC = Probable Effects Concentration (MacDonald et al. 2000); **Bold** = above PEC; PEQ = Probable Effects Quotient, metal value/PEC; Mean PEQ = Σ PEQ/#metals; Σ PEQ = sum PEQs; Subscript qualifiers: 05 = estimated value; detected below PQL; 09 = sample was diluted during analysis; 11 = Estimated value, matrix interference.

Table 13
Fine Sediment Character, Fall 2015: Total Recoverable Cadmium, Lead, and Zinc
Concentrations (mg/kg) at Center Creek Stations

Station/ Sample No.	#6 153614	#5 153560	#4 154099	#3 153613	#2 153610	#1 153611	PEC Threshold	PEQ Threshold
Cadmium (PEQ)	0.973 ₁₁ (0.195)	2.550 ₁₁ (0.512)	5.610 (1.127)	13.500 (2.711)	11.4 (2.289)	8.940 (1.795)	4.98	>1.0
Lead (PEQ)	16.8 (0.13)	36.6 (0.286)	110.0 (0.859)	102.0 (0.797)	167.0 (1.305)	117.0 (0.914)	128.0	>1.0
Zinc (PEQ)	140.0 (0.31)	382.0 (0.832)	984.0 (2.144)	2540.0 ₀₉ (5.534)	2960.0 ₀₉ (6.449)	1570.0 (3.420)	459.0	>1.0
ΣPEQ	0.635	1.630	4.130	9.042	10.043	6.129	--	≥7.92
Mean PEQ	0.212	0.543	1.377	3.014	3.348	2.043	--	≥1.11

PEC = Probable Effects Concentration (MacDonald et al. 2000); **Bold** = above PEC; PEQ = Probable Effects Quotient, metal value/PEC; Mean PEQ = ΣPEQ/#metals; ΣPEQ = sum PEQs; Subscript qualifiers: 05 = estimated value, detected below PQL, 09 = sample was diluted during analysis, 11 = Estimated value, matrix interference





4.0 Discussion

This biological assessment and metals characterization study of Center Creek, Jasper County, was conducted in the fall 2014 and fall 2015. A similar study of wadeable streams is usually conducted over fall and following spring seasons. Because Center Creek discharge was too great to sample in the spring using methods described in the SMSBPP (MoDNR 2012), the stream was sampled during the following fall season. All other aspects of the study are consistent with a typical biological assessment and metals characterization study.

The discussion section includes a stream habitat assessment, biological assessment, which includes a macroinvertebrate community assessment and general physicochemical water quality analyses, dissolved metals analyses in surface water, and total metals characterization of the benthic fine sediment. The discussion highlights, consolidates and compares notable results with the intention of identifying areas of interest and potential threats.

4.1 Stream Habitat Assessment

Stream habitat quality was assessed during this study. Overall, Center Creek contained relatively high quality stream habitat. Stream habitat assessment scores decreased slightly from the upstream stations through the next two stations downstream, presumably due to an increase in urbanization. Habitat quality increased to 100 percent of the control average at station #3, which was in the center of the study area. Habitat remained very good at station #2, downstream from Webb City and Oronogo, as well as at station #1, which is downstream from Carl Junction. Overall, stream habitat quality within and in close proximity to Center Creek was not an obvious influence on results in this assessment.

4.2 Biological Assessment

A biological assessment includes examination of the macroinvertebrate community composition and physicochemical water quality constituents, all of which are necessary to gauge the health of the stream. Macroinvertebrate community analyses include examination of primary and secondary biological metrics. Physicochemical water quality constituents are highlighted if notable. The discussion integrates notable results to identify areas of interest and potential influences.

4.2.1 Macroinvertebrate Community Analyses: Primary Metrics

Macroinvertebrate community analyses were conducted using primary metrics for the 2014 and 2015 seasons. The MSCI scores, support categories, and individual metric scores followed a mostly similar trend in both years. The upstream stations (#6, #5, and #4) attained MSCI scores of 20 and were consistently fully supporting of the AQL. Station #3 also was consistently fully supporting, although the MSCI score dropped from upstream to a slightly lower score of 18 during both years due to elevated BI values. Station #2 was consistently partially supporting of the AQL with MSCI scores of 14. The TR, EPTT, and BI metrics contributed each year to the lower score at station #2. Station #1 was fully supporting with an MSCI of 16 in 2014 and partially supporting with a score of 14 in 2015. The lower MSCI in 2015 was caused by the addition of a lower TR score compared to 2014. The EPTT and BI metrics were less than optimum during both years and influenced the MSCI and support categorization. These individual metric scores indicate more tolerant communities with substantially fewer taxa in stations #2 and #1.

The BI metric value consistently increased to less than optimum levels at stations #3, #2, and #1. The BI metric is an indicator of tolerance of the community to organic influences or other disturbances. At first glance, it appears that an influence upstream of #3 may be affecting the communities of downstream stations. If there were only one influence upstream of station #3 that was contributing to all downstream stations, one would expect the BI to be higher at station #3, and that the metric value or influence would decrease with distance downstream. However,

the BI remained relatively constant and even increased downstream in station #1 during both years. These factors suggest that there may be more than one influence, potentially separate organic or disturbance influences that are associated with the lower three stations.

4.2.2 Macroinvertebrate Community Analyses: Secondary Metrics

Based on the DMT composition, it is apparent that the overall macroinvertebrate community in Center Creek was made up of somewhat different taxa than those that are found in BIOREF streams of the Ozark/Neosho EDU. Generally, among the dominant taxa observed in BIOREF streams, two DMT, *Paraleptophlebia* sp. (mayflies) and *Marilia* sp. (caddisflies), were absent or were found in much lower abundance among all Center Creek stations. The communities of the two downstream Center Creek stations, however, were substantially different from both BIOREF streams and the remaining upstream stations.

The BIOREF DMT comparison identified stations #2 and #1 as containing different macroinvertebrate communities than both BIOREF streams and the remaining upstream stations. In 2014, 7 of the 10 BIOREF DMT were either absent or substantially reduced in abundance at station #2; these DMT were also lower in abundance at station #2 than upstream stations. Eight of the ten BIOREF DMT followed a similar trend in 2015. Six of the ten BIOREF DMT were absent or reduced in abundance at station #1; these DMT were much less abundant in station #1 than upstream stations during both years. This indicates the macroinvertebrate communities at stations #2 and #1 were different from those in BIOREF streams, as well as the upstream stations in Center Creek. These trends suggest that the macroinvertebrate communities at the two most downstream stations were influenced by some factor(s) in Center Creek.

Several of the BIOREF DMT were consistently absent or much less abundant at stations #2 and #1, as well as other stations in Center Creek. *Psephenus herricki* made up a much lower percentage and was ranked lower than the upstream stations. *Stenelmis* sp. decreased substantially at stations #2 and #1 during both seasons. *Baetis* spp. were present among upstream stations (#6 to #3) during both seasons, but they were absent or much reduced in downstream stations #2 and #1. *Baetis* spp. are generally considered sensitive to organic influences or disturbance, but they are also thought to be intolerant of heavy metals contamination (Kiffney and Clements 1994). The riffle beetle *Optioservus sandersoni* was absent or much reduced at stations #2 and #1 relative to upstream stations. *Optioservus* spp. are considered to be sensitive to organic pollution, and Clements et al. (2000) considered *Optioservus* spp. to be sensitive to heavy metals. It appears that these taxa are sensitive to influences at these stations, and that these influences may be mine related.

Further examination of taxa at the order, family, and genus level (Appendix A) was used to identify specific changes and potential contributors to the suboptimum MSCI scores at stations #2 and #1. Ephemeroptera taxa are generally considered sensitive to organic pollution or disturbance. Ephemeroptera (mayfly) taxa are also considered to be very sensitive to heavy metals pollution (Burrows and Whitton 1983; Carlisle and Clements 1999, Clements et al. 1988; Clements 1994; Clements and Kiffney 1995; Clements et al. 2000; Kiffney and Clements 1994; Soucek et al. 2000; Poulton et al. 2009). The number of Ephemeroptera taxa changed dramatically from upstream stations to downstream stations in both 2014 and 2015. Stations #6

through #3 contained between 19 to 21 mayfly taxa in 2014 and between 17 to 20 mayflies in 2015. By comparison, stations #2 and #1 each contained five mayflies in 2014, and four and eight mayflies respectively, in 2015(Appendix A).

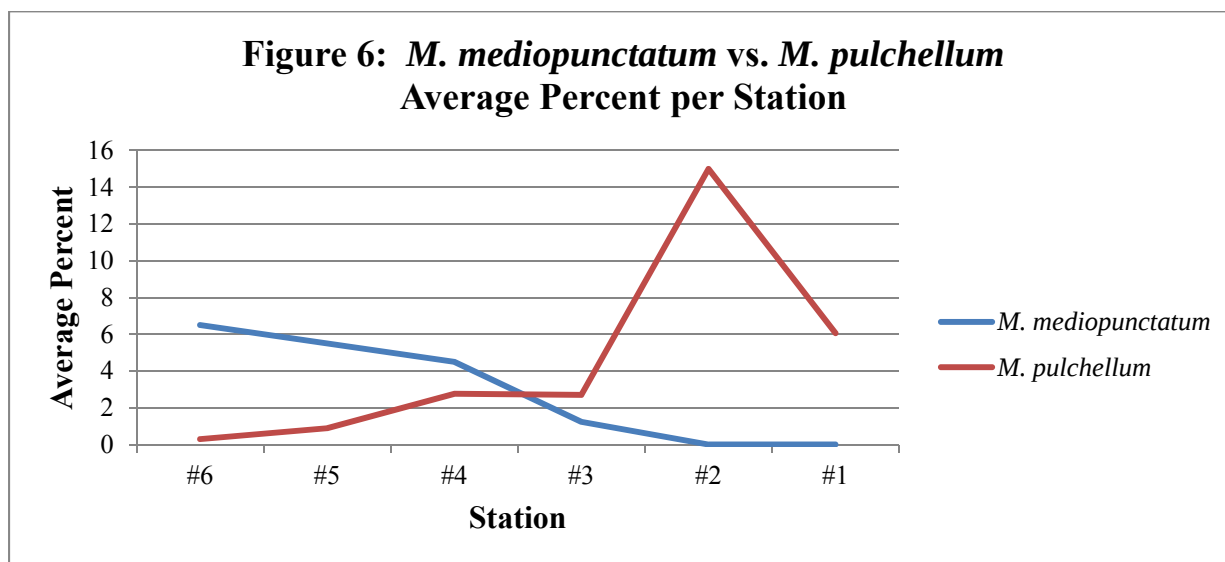
Within the Ephemeroptera, the family Heptageniidae is generally considered to be sensitive to heavy metals pollution (Clements et al. 2000). A proportionally large number of heptageniid mayflies were present in low abundance or absent among downstream stations. Heptageniid taxa such as *Maccaffertium bednariki*, *M. mediopunctatum*, *M. pulchellum*, *M. terminatum*, *Leucrocuta* sp., and *Stenacron* sp. were consistently found in the upstream stations #6, #5, #4, and #3. *Stenonema femoratum* was consistently present at stations #5 and #4, intermittently found at #6, and consistently absent at #3. *M. pulchellum* was the only heptageniid present in stations #2 and #1 in 2014. In 2015, *M. pulchellum* was abundant, whereas one *Stenacron* sp. was found in station #2. Station #1 contained a large number of *M. pulchellum*, one *M. terminatum* and two *Stenacron* sp. in 2015. *M. pulchellum* is generally considered to be sensitive to organic pollution, which at this point contradicts organic influences as being a possible explanation for impairment. As a member of the family Heptageniidae, it is considered sensitive to elevated heavy metals concentrations.

Past observations in mine related studies (MoDNR 2010a, 2013a, 2013c, 2015a) have suggested that *M. mediopunctatum* is particularly sensitive to influences in many mine related streams. In this project, *M. mediopunctatum* was prevalent among the top 10 DMT at upstream stations #6, #5, and #4. Conversely, the mayfly was consistently absent, or present in substantially lower abundance, in downstream stations #3, #2, and #1 (Figure 6). The implication is that an influence in the downstream portion of the Center Creek study reach is similar to that found in other metals related studies, and that this mayfly species is also sensitive to an influence present in these downstream stations. It also suggests that this species, and others listed above within the family Heptageniidae, may be good indicators of metals related influences.

Interestingly, while *M. mediopunctatum* decreased in abundance, the number of *M. pulchellum* increased substantially in the same downstream stations (Figure 6). In fact, *M. pulchellum* increased to a level of dominance in these downstream stations. Loss of a species within the family and a substantial increase in abundance of another species within that same family would mask a notable change in the community structure using only family level identification. It is clear that using family level identification is not effective in assessing streams with metals related influences.

4.2.3 General Water Quality

Physicochemical water constituents were examined from surface water in all Center Creek stations in 2014 and 2015. All of the general water quality constituents were within WQS (MoDNR 2014c) threshold concentrations; however, several variables exceeded the EPA recommended guidelines (EPA 2000) at all stations. Turbidity, total nitrogen, nitrate+nitrite as N, and total phosphorus exceeded EPA guidelines at all stations in both years. These constituents, plus conductivity and sulfate, were elevated and notable at times compared to upstream stations.



As mentioned earlier, the less than optimum BI indicated that organic pollutants or disturbance influenced the community at station #3. Water quality constituents at station #3 were not notable when compared to other stations. Therefore, it appears that the elevated BI at station #3 was not obviously related to organic influences, but likely due to some other disturbance. Station #3 is immediately downstream from Bens Branch, which is a tributary of Center Creek that has been extensively mined in the past. Much of the Bens Branch upper watershed is barren or sparsely vegetated, presumably due to past mining effects.

General water quality samples were collected at Bens Branch concurrent with this project in 2015, by the Department's Hazardous Waste Program. The sulfate concentrations in Bens Branch were 211 - 495 mg/L, which was approximately 10- to 20-times higher than levels observed in Center Creek. Conductivity was between 764 – 1079 $\mu\text{S}/\text{cm}$, total nitrogen was as high as 0.40 mg/L, nitrate + nitrite as N reached 0.27 mg/L, and turbidity was 2.5 NTU. The latter three constituents were well above EPA suggested guidelines (EPA 2000). We did not observe substantial contributions at station #3 from Bens Branch during this project, as water quality constituents were not exceptional, and the macroinvertebrate community consistently attained fully supporting status. However, given suitable conditions, Bens Branch has the potential to contribute these water quality constituents in much higher concentrations to Center Creek.

Water quality constituents, such as conductivity, total nitrogen, nitrate+nitrite as N, chloride, and total phosphorus were at times elevated at station #2 relative to the upstream stations. Sulfate was the only water quality constituent that was consistently elevated relative to upstream stations. Station #2 was partially supporting of the AQL in both years, but it is unlikely that sulfate in these concentrations was a substantial contributor to the altered aquatic community. Concentrations of constituents did fluctuate from one year to the next and may have reached effective levels at some point between sampling, potentially from some organic influence such as a wastewater treatment facility (WWTF). However, sulfate, (Allert et al. 2008, 2011), total nitrogen, and nitrate+nitrite as N (Allert et al. 2009) are also associated with heavy metals

mining in southeast and southwest Missouri. The station #2 watershed has been extensively mined for heavy metals in the past.

Conductivity, total nitrogen, nitrate+nitrite as N, chloride, and total phosphorus were at times elevated at station #1 relative to upstream stations. In fact, these constituents were found in their highest concentrations at station #1 in 2014, which may result from an upstream organic influence, such as WWTFs or other sources. The BI values were also the highest among all stations at #1, which suggests that the macroinvertebrate community was influenced by these constituents. However, the macroinvertebrate community at station #1 in 2014 was fully supporting of the AQL while these constituents were slightly elevated. This observation suggests that the concentrations of variables were not sufficient to substantially influence the community. In 2015, only sulfate and total phosphorus were elevated relative to all upstream stations while station #1 reached only partially supporting of the AQL. Water quality constituent levels did fluctuate slightly from one year to the next, but all constituents were actually slightly higher in 2014 than in 2015 when the MSCI was lower. This also suggests that water quality constituents alone were probably not a substantial influence on the community. These and other variables may have reached effective concentrations at some time between sampling events due to some organic input such as WWTFs, but we did not observe it in 2014 and 2015. In summary, only sulfate and total phosphorus were consistently found in the highest concentrations at station #1 and it is not likely that the availability or concentrations observed were substantial influences on the aquatic community composition. Again, constituents such as sulfate (Allert et al. 2008, 2011), total nitrogen, and nitrate+nitrite as N (Allert et al. 2009) are also associated with heavy metals mining in southeast and southwest Missouri. Station #1 watershed has been extensively mined for heavy metals in the past.

4.3 Surface Water: Dissolved Metals

Dissolved metals concentrations in surface water were quantified for all Center Creek stations in 2014 and 2015. Several trends were consistently observed among stations. When dissolved metals were present, concentrations increased from upstream to downstream. Concentrations increased substantially at stations #4 and #3, consistently reaching the highest concentrations at station #2, before always declining downstream at station #1. Cadmium was present during both years at station #2, and it exceeded the chronic WQS concentration in 2015. Cadmium was observed at stations #3 and #1 only in 2015, but in concentrations below WQS. Lead was observed in 2014 only at stations #2 and #1. Zinc consistently increased from upstream to downstream, most noticeably at stations #4, #3, #2, and #1. Zinc concentrations reached highs near the chronic WQS at station #2, before consistently decreasing at station #1. Station #2 was partially supporting during both years, whereas station #1 was partially supporting only in 2015. Poulton et al. (2009) found a significant correlation between biotic condition scores and (pore water) cadmium concentrations in southwest Missouri. Additionally, Allert et al. (2011) indicated that the risk of toxicity was primarily due to high zinc concentrations downstream from mine sites. Besser and Rabeni (1987) showed strong correlations of dissolved metal concentrations with metal concentrations in crayfish survival and growth. Dissolved metals concentrations may have affected the macroinvertebrate community at the three downstream stations, and subsequently the beneficial use for the protection of AQL at stations #2 and #1.

Elevated dissolved metals concentrations at several stations point to potential areas of influence. Potential sources of dissolved metals are discussed for stations #3, #2, and #1 in this paragraph.

1) The Bens Branch watershed may be a contributor of cadmium and/or zinc to Center Creek station #3. Bens Branch, which is immediately upstream of station #3, was concurrently sampled for dissolved metals in 2015 by the Department's Hazardous Waste Program; dissolved cadmium (7.73 µg/L) was found over 12-times higher than the chronic WQS concentration (0.63 µg/L) at a hardness as CaCO₃ of 385 mg/L; dissolved zinc (2240 µg/L) was over six-times higher than the acute and chronic toxicity threshold (367 µg/L) concentration (MoDNR 2014c). However, station #3 was fully supporting of the AQL during both years of study. The effects of Bens Branch may have been realized by the altered macroinvertebrate community mentioned earlier and by the elevated BI. Elevated metals concentrations in the Bens Branch watershed suggest that the tributary has enormous potential to contribute these toxic dissolved metals to Center Creek given suitable conditions. 2) A heavily-mined site upstream of station #2, which is now part of an EPA remediation (wetland) area, may be a contributor of the elevated concentrations of dissolved cadmium, lead, and zinc, some near or exceeding WQSs. Station #2 was also partially supporting of the AQL during both sample years. 3) Concentrations of dissolved metals at station #1 were consistently lower than #2; however, concentrations remained higher than other upstream stations. This suggests that either dissolved metals were available through surface runoff in the immediate watershed, groundwater source, or that dissolved metals were contributed by instream sources (fine sediment). Station #1 was partially supporting of the AQL in 2015 when dissolved metals exceeded or were near WQS thresholds. Tributaries of Center Creek should be sampled for dissolved metals to identify points of influence.

4.4 Fine Sediment: Total Metals Characterization

The heavy metals character of benthic fine sediment (<2.0mm) was examined in Center Creek during 2014 and 2015. Total cadmium, lead, and zinc concentrations were slightly higher at station #5 than station #6, but total metals associated with fine sediment at these stations did not exceed individual PECs. A trend of increasing metals concentrations in fine sediment was observed downstream of these two stations.

Heavy metals concentrations associated with benthic fine sediment were potentially toxic to the aquatic community at four of the six stations in Center Creek. Heavy metals exceeding threshold levels were found in fine sediment at stations #4, #3, #2, and #1. Cadmium, lead, and zinc individually, and as a mixture or combination, followed an increasing trend from upstream to downstream, reaching their maxima at station #2 before consistently decreasing at station #1. The greatest potential for toxicity to the aquatic community appears to be at stations #3, #2, and #1, based on the number of metals that were present in high concentrations. Heavy metals associated with benthic fine sediment may have contributed to the consistent partial support of the AQL in station #2 and intermittent partial support at station #1.

Potential sources for fine sediment laden with toxic metals are included below. This is not a complete list of threats, but it identifies general areas of interest. 1) Grove Creek, a tributary of Center Creek upstream of station #5, may be contributing fine sediment with total metals concentrations below PEC thresholds. 2) Uncontrolled runoff to tributaries upstream of or near

station #4 may be contributing potentially toxic metals associated with fine sediment, which may be related to the watershed of the Duenweg area. 3) Station #3, as mentioned earlier, is immediately downstream of Bens Branch, another tributary of Center Creek. Fine sediment collected in 2015 from Bens Branch contained cadmium (73.7 mg/kg), lead (179 mg/kg), and zinc (9640 mg/kg); each of these metals greatly exceeded the PECs and mixture or combination of metals thresholds. Bens Branch has the potential to contribute potentially toxic levels of total metals to Center Creek station #3. 4) Station #2 had the highest concentrations of total metals. This station is immediately downstream from an EPA remediation site that was previously mined. Uncontrolled runoff and/or tributary flow may contribute the heavy metals laden fine sediment to station #2. 5) Because total metals concentrations were consistently lower at station #1 than #2, it appears that fine sediment contains lower concentrations of total metals, or that less metals rich fine sediment is available to be transported to the stream from the watershed at station #1. As shown by the study in the Bens Branch watershed, tributaries of Center Creek should be sampled for total metals associated with fine sediment to identify areas of influence and efficacy of remediation.

Interestingly, concentrations of total cadmium, lead, and zinc decreased substantially from 2014 to 2015 in the fine sediment collected at stations #3, #2, and #1. One explanation may be that the fine sediment containing higher concentrations of heavy metals was not evenly distributed on the substrate and only sediment with lower concentrations was collected in 2015. Samples were not collected from the exact same locations in each station during each year, so a patchy distribution of heavy metals laden fine sediment could explain the decreasing concentrations. It is unlikely however, that only fine sediment with lower concentrations was collected from all downstream stations if fine sediment with high concentrations was available. Furthermore, metals concentrations in the upstream stations #6, #5, and #4 were similar to or slightly higher than the following year, which implies that sample collection methodology and effectiveness did not contribute to lower concentrations at stations #3, #2, and #1. This observation suggests that some other factor(s) downstream of station #4 (discussed below) contributed to the decrease in total metals concentrations.

4.4.1 Remediation Efficacy

An alternative explanation is that fine sediment with elevated metals concentrations was removed by high flows and replaced by fine sediment with lower concentrations of heavy metals. The implication is that remediation efforts to detain material with higher concentrations of metals from Center Creek are working. In fact, remediation efforts are being conducted in Center Creek from the west (downstream) and moving to the east (upstream) (Don Van Dyke, MoDNR Hazardous Waste Program, pers. comm. 2016).

Station #1 is the farthest west station and most downstream station in the study. Total metals concentrations decreased substantially from 2014 to 2015. Station #1 is immediately downstream of the Blackcat Road mine remediation site. The decrease from one year to the next in this location suggests that the material with elevated metals is moving out of the area and being replaced by fine sediment with lower concentrations. This suggests that fine sediment with higher concentrations of metals are being detained as a result of remediation efforts.

Station #2 is the next station to the east and upstream of station #1. Station #2 is directly downstream of an EPA remediation (wetland) site that was in-progress at the time of this study. Total metals were observed in the highest concentrations at station #2 during both years, but they were substantially lower in 2015. Again, this trend potentially suggests that fine sediment with higher metals concentrations is being detained or prevented from entering the stream, and remediation efforts may be having their desired effect.

Farther east and upstream, station #3 is directly downstream of Bens Branch which, as discussed earlier, has the potential to deliver high concentrations of total metals and dissolved metals to Center Creek. However, concentrations were lower at station #3 in 2015 as well. Interestingly, remediation efforts have taken place in the watershed of Bens Branch. As was observed downstream, it appears that new input is being detained and that remediation is apparently working to decrease the fine sediment with high concentrations of metals.

The immediate watersheds of upstream (east) stations #4, #5, and #6 are not being remediated, and perhaps not coincidentally, total metals concentrations associated with fine sediment did not substantially decline. In some cases, metals concentrations even increased from 2014 to 2015. Station #4 contained potentially toxic metals concentrations that remained at similar levels during both years, which suggests that toxic metals are not being prevented from entering the stream at that point. The concentrations upstream in stations #5 and #6 were lower than downstream, but the concentrations were similar between years, which still identifies a difference from downstream stations and that metals are not being detained. This poses the question if remediation were taking place in those upstream stations, would the concentrations of metals be even lower at all stations? At this point, it appears that the reason for the decline in downstream stations may be due to remediation efforts. However, more data are needed to determine if this is an actual trend of decreasing total metals concentrations in the fine sediment.

Although total metals concentrations in fine sediment were lower in 2015, cadmium, lead (at #2), and zinc were still found in potentially toxic concentrations at stations #3, #2 and #1. Cadmium or zinc also exceeded thresholds at station #4. Remediation efforts should continue throughout the study area, and move farther to the east and upstream to include other potentially affected areas.

4.4.2 Potential Sediment Pulse

It is possible that during high flow events, the uncontrolled flow of fine sediment containing heavy metals from the watershed of upstream stations may be contributing to the benthic metals concentrations that are found in the downstream stations. If remediation efforts in the immediate watershed of downstream stations (i.e. #3, #2, #1) are having the desired effect of preventing material from entering the stream, the metals concentrations that remain may be a result of a pulse (or pulses) of fine sediment originating from the upper watershed with elevated total metals concentrations (although slightly lower than downstream stations).

Just as the downstream stations may have been affected by uncontrolled influences from the upper watershed, Center Creek downstream of the study area may in turn be affected by a fine sediment pulse (or pulses) from downstream stations. Fine sediment containing higher

concentrations of total metals may have moved in pulses from the downstream stations during seasonal high flow events (Besser et al. 2007). If so, elevated metals concentrations may be observed in the fine sediment downstream of affected stations identified in this study. Station #2 consistently had the highest metals concentrations that decreased from 2014 to 2015, suggesting that the influence moved downstream. Metals concentrations also decreased at station #1, suggesting the material has not yet reached, or has moved beyond station #1. Fine sediment downstream of the study area should be assessed for total metals character to determine if a pulse has moved beyond the assessed reach and to identify the downstream extent of elevated metals associated with fine sediment.

4.5 Fine Sediment Metals Influence on Surface Water Dissolved Metals

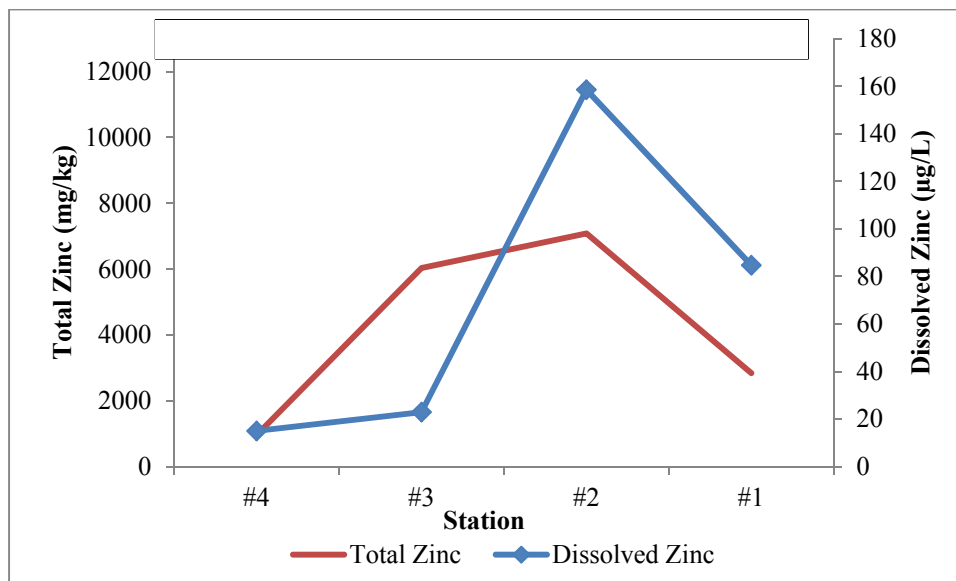
Trends in total metals associated with the benthic fine sediment followed a trend that was similar to water quality constituents and dissolved metals. Higher conductivity, sulfate (Allert et al. 2008), total nitrogen, and nitrate+nitrite as N (Allert et al. 2009) are associated with heavy metals mining and were found at their maxima at station #2 before decreasing at station #1. Furthermore, Brumbaugh et al. (2007) found that sulfate and heavy metals in interstitial waters tracked closely with metals concentrations in the sediment.

Dissolved heavy metals concentrations in Center Creek surface water could be a function of the total heavy metals in the fine sediment. Total cadmium, lead, and zinc in the fine sediment followed an increasing trend from upstream to downstream, reaching the highest (or near) concentrations at station #2, before decreasing slightly at station #1. When dissolved cadmium, lead, and zinc were observed in surface water, they followed a trend similar to metals in the sediment, in which levels were highest at station #2 before decreasing at station #1. Trends for average dissolved and total zinc from station #4 to station #1 are presented in Figure 7. As mentioned by Brumbaugh et al. (2009), localized physical and chemical conditions may allow for the release of metals from fine sediment particles into the pore water, and their results suggested that there can be a strong association between pore water and surface water concentrations. As such, pore water should be analyzed from Center Creek stations.

However, when comparing trends for dissolved and total metals between 2014 and 2015, there is not a clear association. Total metals were generally much higher in 2014 than 2015, whereas dissolved metals were generally similar in both years or even elevated in 2015. There was no obvious proportional increase in dissolved metals associated with higher total metals. This observation suggests that these constituents may be independent fractions and not a function of the other. Although there is an association between the media, the dissolved fraction is not merely a function of the amount of metals in the fine sediment. Rather, the potential exists for toxic sediment metals to contribute to surface water dissolved metals concentrations. The release of dissolved metals from bulk sediment can be related to suitable physical and chemical conditions (Brumbaugh et al. 2009).

Researchers have found strong negative correlations between sediment or pore water metals concentrations and aquatic biota (Gale et al. 2004; Besser et al. 2009a; Poulton et al. 2009). Earlier, Figure 6 showed a change in species level taxa dominance especially prevalent at station #2 and #1. Elevated total and dissolved metals may have influenced the macroinvertebrate

community composition, and ultimately the consistent partial support categorization at station #2 and intermittent partial support of the AQL at station #1. Pore water, surface water, groundwater and benthic sediment should be periodically collected from Center Creek and analyzed for metals concentrations.



5.0 Conclusions

The objectives have been addressed. The stream habitat, macroinvertebrate community, and physicochemical water quality have been assessed. Dissolved metals concentrations in the surface water and total metals in the fine sediment (i.e. metals character) have been evaluated.

Testing of the null hypotheses resulted in the following:

- 1) Stream habitat quality at Center Creek will be comparable to the stream habitat control.

This null hypothesis was not rejected. Stream habitat quality at Center Creek was comparable to the SHAPP control streams.
- 2) MSCI scores will indicate that Center Creek stations are fully supporting of the beneficial use – AQL, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the 2014 and 2015 sample seasons.

These hypotheses were rejected for two stations. Center Creek #2 was partially supporting of the AQL in both 2014 and 2015, and #1 was partially supporting in 2015. The TR, EPTT, and BI biological metric values contributed to the lower individual metric scores at stations #2 and #1.

- 3) Dominant macroinvertebrate taxa composition (a secondary biological metric) will indicate that Center Creek macroinvertebrate communities are similar to those of BIOREF streams.

This hypothesis was rejected. Dominant macroinvertebrate taxa comparisons indicated that Center Creek macroinvertebrate communities were different from BIOREF streams. Several taxa that were dominant in the BIOREF streams were absent or found in much lower abundance in all Center Creek stations. The macroinvertebrate communities of stations #2 and #1 were much different from upstream stations. Furthermore, a number of apparently sensitive mayfly taxa were not present or were much reduced at stations #2 and #1 compared to upstream stations.

- 4) Physicochemical water quality constituents will be within acceptable parameters, as specified in Missouri's Water Quality Standards (MoDNR 2014c) and will not be notable compared to other thresholds or among stations.

This hypothesis was rejected. Physicochemical water quality constituents were within acceptable MoDNR WQSs (2014c). However, several measured factors exceeded EPA (2000) suggested guidelines at all stations, and concentrations of these and other constituents at stations #2 and #1 were intermittently elevated compared to other stations.

- 5) Dissolved metals in the surface water will be within acceptable hardness-dependent limits outlined in Missouri's WQS.

This hypothesis was rejected for Center Creek. Cadmium intermittently exceeded WQS (MoDNR 2014c) at station #2, and dissolved lead was intermittently observed at stations #2 and #1. Zinc consistently followed an increasing trend to a level near WQS threshold concentrations at station #2 before decreasing at station #1.

- 6) Heavy metals (i.e. cadmium, lead, zinc) concentrations associated with benthic fine sediment will be below threshold levels in Center Creek.

This hypothesis was rejected for Center Creek. Heavy metals associated with fine sediment exceeded individual and mixture or combination of metals thresholds at #4, #3, #2, and #1 during both years.

6.0 Recommendations

- 1) Sample Center Creek stations for dissolved metals to identify potential sources and trends.
- 2) Sample Center Creek stations for total metals in fine sediment to determine the efficacy of remediation.
- 3) Sample tributaries of Center Creek for dissolved metals to identify sources.

- 4) Sample tributaries of Center Creek for total metals in fine sediment to identify sources.
- 5) Fine sediments should be sampled downstream of station #1 to determine if metals-contaminated sediment is moving as a pulse through the system and to estimate the downstream extent of potentially toxic total metals.
- 6) For future studies, analyze pore water concentrations in Center Creek stations.
- 7) Continue remediation in Center Creek watershed and include areas upstream if found to be potentially influential.

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Appendix A

Macroinvertebrate Bench Sheet Report: Center Creek, Jasper County, Missouri Fall 2014 and Fall 2015

Grouped by year and station (upstream to downstream)

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14900], Station #6, Sample Date: 9/16/2014 11:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	6	4	
AMPHIPODA			
Hyaella azteca			3
ARHYNCHOBDELLIDA			
Erpobdellidae		-99	
BASOMMATOPHORA			
Ancylidae	2	10	1
Menetus			-99
COLEOPTERA			
Ancyronyx variegatus	2	1	
Dubiraphia		9	39
Ectopria nervosa		6	
Macronychus glabratus	5	1	9
Optioservus sandersoni	3		
Psephenus herricki	30	46	
Scirtidae			3
Stenelmis	24	30	6
DECAPODA			
Orconectes macrus	1		
Orconectes neglectus	-99	2	3
DIPTERA			
Ablabesmyia		4	2
Ceratopogoninae		4	
Chironomidae	1		
Cladotanytarsus		3	
Corynoneura			1
Cricotopus bicinctus			1
Cricotopus/Orthocladus	3	2	
Cryptochironomus		2	
Cryptotendipes		5	
Dicrotendipes		6	
Hexatoma	1		
Labrundinia			12
Microtendipes		2	
Nanocladius			1
Paralauterborniella			2
Paratanytarsus			1
Paratendipes		2	
Polypedilum flavum	14		1
Polypedilum illinoense grp			2
Polypedilum scalaenum grp			1
Rheocricotopus	1		1
Rheotanytarsus	1		1
Simulium			3
Stempellina		1	
Stempellinella	7	1	3
Stenochironomus		1	
Stictochironomus		1	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14900], Station #6, Sample Date: 9/16/2014 11:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Tabanus	2		
Tanytarsus	1	1	1
Thienemanniella	2		1
Thienemannimyia grp.	2		9
EPHEMEROPTERA			
Acerpenna	3		
Anthopotamus	4	2	
Apobaetis		1	
Baetis	47		2
Caenis anceps	19	32	4
Caenis latipennis		18	22
Choroterpes	13		
Ephemera simulans	43	20	-99
Heptageniidae	62		
Hexagenia limbata		5	10
Isonychia bicolor	43		-99
Leptophlebiidae		1	1
Leucrocuta	14		
Maccaffertium bednariki	17		
Maccaffertium mediopunctatum	107		
Maccaffertium pulchellum			4
Maccaffertium terminatum	34		
Procloeon		2	
Stenacron	8	12	3
Stenonema femoratum		1	12
Tricorythodes	22	5	17
HEMIPTERA			
Corixidae		1	
ISOPODA			
Lirceus		1	
LEPIDOPTERA			
Petrophila	1		
LUMBRICINA			
Lumbricina	5		
MEGALOPTERA			
Corydalis	10		
NEOTAENIOGLOSSA			
Elimia	2	2	6
Hydrobiidae		5	
ODONATA			
Argia	2	4	12
Calopteryx			6
Gomphidae	-99	1	
Hetaerina			17
PLECOPTERA			
Agnetina flavescens	25		
Neoperla	14	4	
RHYNCHOBDELLIDA			
Glossiphoniidae			-99

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14900], Station #6, Sample Date: 9/16/2014 11:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
TRICHOPTERA			
Ceratopsyche morosa grp	2		
Cheumatopsyche	15		4
Chimarra	1		
Helicopsyche	8		
Hydroptila	2		2
Oecetis		1	37
Pycnopsyche			1
Triaenodes			43
TRICLADIDA			
Planariidae	2		
TUBIFICIDA			
Branchiura sowerbyi		1	
Enchytraeidae		1	
Tubificidae	3	19	15
UNIONIDA			
Unionidae		1	
VENEROIDA			
Corbicula	-99	2	-99
Pisidiidae	-99		2

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14901], Station #5, Sample Date: 9/16/2014 1:10:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	16		2
AMPHIPODA			
Hyalella azteca			66
ARHYNCHOBDELLIDA			
Erpobdellidae			-99
BASOMMATOPHORA			
Ancylidae	5	14	
Menetus			7
Physella		-99	
Planorbella	3		
COLEOPTERA			
Dubiraphia		8	33
Ectopria nervosa	2	2	
Macronychus glabratus			10
Optioservus sandersoni	6		
Psephenus herricki	19	13	
Stenelmis	74	30	3
DECAPODA			
Orconectes macrus	-99	-99	
Orconectes neglectus	-99	1	1
DIPTERA			
Ablabesmyia	1	6	1
Ceratopogoninae		5	1
Chironomus		4	
Chrysops		1	
Cladotanytarsus		5	
Clinotanytus			1
Cricotopus/Orthocladus	3	2	
Cryptochironomus		1	1
Cryptotendipes		10	4
Dicrotendipes	9	2	1
Labrundinia			16
Microtendipes	1	1	1
Parakiefferiella	1		
Paralauterborniella		2	7
Paratendipes		1	
Polypedilum flavum	5		
Polypedilum halterale grp		1	
Polypedilum illinoense grp		1	2
Polypedilum scalaenum grp	2	2	4
Procladius		5	
Stempellinella			4
Tabanus	1		
Tanytarsus	1	10	7
Thienemanniella	2		2
Thienemannimyia grp.	8		4
EPHEMEROPTERA			
Acerpenna	17		

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14901], Station #5, Sample Date: 9/16/2014 1:10:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Anthopotamus	72	1	
Baetis	10		
Caenis anceps	38	23	
Caenis latipennis		45	9
Choroterpes	6	4	
Ephemera simulans	64	15	
Hexagenia limbata		7	7
Isonychia bicolor	8		
Leptophlebiidae	2	6	
Leucrocuta	13		
Maccaffertium bednariki	16		
Maccaffertium mediopunctatum	89		1
Maccaffertium pulchellum	9	2	
Maccaffertium terminatum	2		
Proclleon		2	1
Stenacron	9	26	
Stenonema femoratum		2	
Tricorythodes	120	6	8
ISOPODA			
Lirceus			3
LUMBRICINA			
Lumbricina		-99	3
LUMBRICULIDA			
Lumbriculidae			1
MEGALOPTERA			
Corydalus	6	-99	
Sialis		-99	
NEOTAENIOGLOSSA			
Elimia	2	-99	42
Hydrobiidae	2	1	
ODONATA			
Argia	7	5	10
Calopteryx			1
Gomphus		1	
Hagenius brevistylus		-99	
Hetaerina			5
Ophiogomphus	-99		
Stylogomphus albistylus		-99	
PLECOPTERA			
Neoperla	7		
Perlesta	12		
RHYNCHOBDELLIDA			
Glossiphoniidae		-99	
TRICHOPTERA			
Cheumatopsyche	15		
Helicopsyche	35		
Hydroptila	4		4
Marilia	1		
Oecetis		1	14

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14901], Station #5, Sample Date: 9/16/2014 1:10:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Pycnopsyche		-99	1
Triaenodes			5
TRICLADIDA			
Planariidae	5		
TUBIFICIDA			
Aulodrilus		2	
Branchiura sowerbyi		4	
Limnodrilus hoffmeisteri		1	
Tubificidae	4	80	12
VENEROIDA			
Corbicula		-99	
Pisidiidae	3		1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14904], Station #4, Sample Date: 9/17/2014 10:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	22	3	2
AMPHIPODA			
Hyaella azteca			48
BASOMMATOPHORA			
Ancylidae	8	1	3
Menetus		1	4
COLEOPTERA			
Ancyronyx variegatus			3
Berosus			1
Dineutus		-99	
Dubiraphia		46	62
Ectopria nervosa	1		
Macronychus glabratus		1	23
Optioservus sandersoni	5		1
Psephenus herricki	5		
Stenelmis	175	11	
DECAPODA			
Orconectes macrus	-99		
Orconectes neglectus	-99		1
DIPTERA			
Ablabesmyia		15	5
Ceratopogoninae		4	3
Chironomidae		2	2
Chironomus		2	
Chrysops		-99	
Cladopelma		8	
Cladotanytarsus		43	
Clinotanytus		1	11
Corynoneura		1	
Cricotopus/Orthocladus	6		5
Cryptochironomus	1	6	
Cryptotendipes		29	2
Dicrotendipes		3	2
Eukiefferiella		1	
Labrundinia			13
Paralauterborniella		6	
Phaenopsectra			1
Polypedilum fallax grp	1		
Polypedilum flavum	1		
Polypedilum halterale grp		15	
Polypedilum illinoense grp			3
Polypedilum scalaenum grp		1	1
Procladius		21	
Pseudochironomus		3	
Rheocricotopus	1		
Rheotanytarsus	1		
Stempellina		6	
Stempellinella	1	2	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14904], Station #4, Sample Date: 9/17/2014 10:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Tanytarsus	4	25	16
Thienemannimyia grp.	3		
Tribelos		1	
EPHEMEROPTERA			
Acerpenna	10		
Anthopotamus	40	1	
Baetidae			1
Baetis	28		
Brachycercus		1	
Caenis anceps	10		
Caenis latipennis		5	3
Choroterpes	3	3	
Ephemera simulans	24	1	1
Hexagenia limbata		1	6
Isonychia bicolor	3		
Leucrocuta	3		
Maccaffertium bednariki	4		
Maccaffertium mediopunctatum	92		1
Maccaffertium pulchellum	82		
Maccaffertium terminatum	4		
Procloeon		7	
Stenacron	7	6	
Stenonema femoratum		2	
Tricorythodes	154		20
HEMIPTERA			
Corixidae		2	
Rheumatobates			5
ISOPODA			
Lirceus		1	3
MEGALOPTERA			
Corydalus	2		
Sialis		-99	
NEOTAENIOGLOSSA			
Elimia	1		-99
ODONATA			
Argia	11	1	28
Dromogomphus			1
Enallagma			18
Gomphidae		2	1
Hagenius brevistylus		1	
Hetaerina			3
Macromia			-99
PLECOPTERA			
Neoperla	13		
Perlesta	18		
TRICHOPTERA			
Cheumatopsyche	2		
Helicopsyche	5		
Leptoceridae	2	1	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14904], Station #4, Sample Date: 9/17/2014 10:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Nectopsyche		3	
Oecetis	4		13
Pycnopsyche			-99
Triaenodes			19
TUBIFICIDA			
Aulodrilus		19	
Branchiura sowerbyi		9	
Limnodrilus hoffmeisteri			1
Quistradrilus multisetosus		1	
Tubificidae	3	28	3
VENEROIDA			
Corbicula	9	19	6

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14903], Station #3, Sample Date: 9/17/2014 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	36		
AMPHIPODA			
Hyaella azteca			143
ARHYNCHOBDELLIDA			
Erpobdellidae		1	
BASOMMATOPHORA			
Ancyliidae		1	1
Lymnaeidae			1
Menetus			7
COLEOPTERA			
Berosus		2	
Dubiraphia		57	17
Ectopria nervosa		2	
Gyrinus		1	1
Lutrochus	2		
Macronychus glabratus			5
Optioservus sandersoni	9		
Psephenus herricki	7	1	
Scirtidae			1
Stenelmis	35	49	
DECAPODA			
Orconectes neglectus		1	-99
DIPTERA			
Ablabesmyia	1	35	3
Ceratopogoninae	2	7	
Cladotanytarsus	4	42	1
Corynoneura		1	
Cricotopus bicinctus	1		1
Cricotopus/Orthocladus	4		
Cryptochironomus		4	
Cryptotendipes		44	
Dicrotendipes	2	13	1
Forcipomyiinae			1
Hexatoma		5	
Labrundinia		1	6
Nanocladus		1	
Parakiefferiella		1	
Paralauterborniella		6	
Polypedilum flavum	1		
Polypedilum illinoense grp			2
Polypedilum scalaenum grp	1	1	
Procladius		10	
Pseudochironomus	1	6	
Rheotanytarsus	9		
Stempellina		2	
Stempellinella	6	13	2
Stenochironomus			2
Tabanus	-99		

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14903], Station #3, Sample Date: 9/17/2014 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Tanytarsus	14	25	8
Thienemannimyia grp.	12	1	
EPHEMEROPTERA			
Acerpenna	2		
Anthopotamus	1	5	
Apobaetis			1
Baetis	9		
Brachycercus		1	
Caenis anceps	12	3	
Caenis latipennis	2	13	2
Choroterpes		1	
Ephemera simulans	13	4	
Heptageniidae	29		1
Hexagenia limbata		4	1
Isonychia bicolor	6		
Leptophlebiidae		3	
Maccaffertium mediopunctatum	6	1	
Maccaffertium pulchellum	6		
Maccaffertium terminatum	25	1	1
Procloeon		3	
Stenacron	7	1	
Tricorythodes	441	4	2
HEMIPTERA			
Rheumatobates			2
ISOPODA			
Lirceus			4
LEPIDOPTERA			
Petrophila	4		
LUMBRICINA			
Lumbricina	-99		
LUMBRICULIDA			
Lumbriculidae		1	
MEGALOPTERA			
Corydalus	2		
Sialis	-99	-99	
NEOTAENIOGLOSSA			
Elimia	8	-99	
ODONATA			
Argia	6	6	10
Enallagma		2	11
Gomphidae		2	
Hagenius brevistylus		1	
Hetaerina	2		1
Macromia		2	-99
PLECOPTERA			
Neoperla	8		
RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14903], Station #3, Sample Date: 9/17/2014 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Helicopsyche	3		
Hydropsychidae	3		
Hydroptila	10		3
Nectopsyche		1	1
Oecetis	11		3
Polycentropus			1
Pycnopsyche			-99
Triaenodes			43
TRICLADIDA			
Planariidae			3
TUBIFICIDA			
Branchiura sowerbyi		6	
Tubificidae		38	
VENEROIDA			
Corbicula	-99	7	
Pisidiidae	3		1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14902], Station #2, Sample Date: 9/16/2014 3:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	24	5	5
AMPHIPODA			
Hyaella azteca			67
BASOMMATOPHORA			
Ancylidae			2
Menetus			1
COLEOPTERA			
Ancyronyx variegatus		2	
Berosus	1	2	
Dubiraphia		23	16
Macronychus glabratus		5	4
Psephenus herricki	1		
Scirtidae			7
Stenelmis	1		
DIPTERA			
Ablabesmyia		4	7
Ceratopogoninae	1	6	3
Chironomidae		3	
Chironomus		7	
Cladopelma		15	
Cladotanytarsus	2	2	
Cricotopus bicinctus	10		
Cricotopus/Orthocladus	23		
Cryptochironomus		6	
Cryptotendipes		2	
Dicrotendipes	1	13	
Hemerodromia	1		
Labrundinia			5
Microchironomus		1	
Nanocladius	1		
Odontomyia			1
Paratanytarsus			10
Phaenopsectra			1
Polypedilum flavum	3		
Polypedilum halterale grp		23	2
Polypedilum illinoense grp		4	4
Procladius		17	1
Pseudochironomus		4	
Rheotanytarsus	5		
Simulium	10		
Stempellinella	8	7	
Stenochironomus		1	
Tabanus	-99		
Tanypus		2	
Tanytarsus	19	15	54
Thienemannimyia grp.	4		
Tribelos		5	
Xestochironomus			1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14902], Station #2, Sample Date: 9/16/2014 3:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
EPHEMEROPTERA			
Acentrella	5		
Apobaetis		2	
Caenis		1	
Maccaffertium pulchellum	295		
Tricorythodes	151		
HEMIPTERA			
Rheumatobates		1	1
ISOPODA			
Lirceus			2
LUMBRICINA			
Lumbricina	2		
MEGALOPTERA			
Corydalus	9		
ODONATA			
Argia	28	1	10
Dromogomphus			-99
Enallagma		2	10
Gomphidae	2		
Macromia			-99
Somatochlora			1
RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			
Cheumatopsyche	50		
Helicopsyche	1		
Hydropsyche	15		
Hydroptila	2		
Leptoceridae	1		
Oecetis	4	1	
Polycentropus		2	2
Pycnopsyche			-99
Triaenodes			90
TRICLADIDA			
Planariidae	2		
TUBIFICIDA			
Aulodrilus		55	
Branchiura sowerbyi		10	3
Limnodrilus hoffmeisteri		2	
Quistradrilus multisetosus		3	
Tubificidae		31	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14905], Station #1, Sample Date: 9/17/2014 1:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	22		
AMPHIPODA			
Hyaella azteca	1		58
Stygobromus		1	
ARHYNCHOBDELLIDA			
Erpobdellidae		1	
BASOMMATOPHORA			
Ancylidae	7	3	1
Menetus		2	
COLEOPTERA			
Ancyronyx variegatus		1	
Berosus	2	25	11
Dubiraphia		20	7
Macronychus glabratus	1		5
Optioservus sandersoni			1
Stenelmis	6	1	10
DECAPODA			
Orconectes neglectus	-99	1	-99
DIPTERA			
Ablabesmyia	2	39	13
Cardiocladius	1	1	
Ceratopogoninae	1	10	
Chironomidae	1	3	1
Cladopelma		2	
Cladotanytarsus		5	
Clinotanypus		1	1
Coelotanypus			1
Cricotopus bicinctus	1		2
Cricotopus/Orthocladius	20		2
Cryptochironomus		5	
Cryptotendipes		2	
Dicrotendipes	2	31	6
Forcipomyiinae	3		
Harnischia		2	
Labrundinia			2
Parachironomus			1
Paratanytarsus			5
Polypedilum flavum	2		
Polypedilum illinoense grp	3	5	2
Procladius		20	3
Pseudochironomus	1	24	
Rheotanytarsus	5	1	1
Simulium	1		
Stempellina		1	
Stempellinella	2	7	
Tanytarsus	9	42	32
Thienemanniella	10		
Thienemannimyia grp.	5	1	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14905], Station #1, Sample Date: 9/17/2014 1:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Tribelos		3	
Zavreliomyia	2		
EPHEMEROPTERA			
Acentrella	20		
Apobaetis		10	1
Caenis latipennis	12	57	22
Maccaffertium pulchellum	60		
Tricorythodes	451	2	
HEMIPTERA			
Corixidae		1	
Rhagovelia	1	1	
Rheumatobates		8	
ISOPODA			
Caecidotea (Blind & Unpigmented)			2
Lirceus		1	7
LUMBRICINA			
Lumbricina	-99	1	2
LUMBRICULIDA			
Lumbriculidae			5
MEGALOPTERA			
Corydalus	1	-99	
ODONATA			
Argia	8	13	19
Calopteryx			1
Dromogomphus			-99
Enallagma		2	33
Epitheca (Epicordulia)			1
Gomphidae	1	1	
Hetaerina			3
Macromia		3	-99
Ophiogomphus	-99		
TRICHOPTERA			
Cheumatopsyche	29		
Helicopsyche	10		
Hydropsyche	1		
Hydroptila	2		
Leptoceridae	1		
Oecetis		1	9
Pycnopsyche			1
Triaenodes			56
TRICLADIDA			
Planariidae			2
TUBIFICIDA			
Aulodrilus		10	1
Branchiura sowerbyi		17	2
Ilyodrilus templetoni		2	
Quistadrilus multisetosus		2	
Tubificidae		9	13
VENEROIDA			

Aquid Invertebrate Database Bench Sheet Report**Center Cr [14905], Station #1, Sample Date: 9/17/2014 1:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Pisidiidae		5	1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15050], Station #6, Sample Date: 10/6/2015 11:15:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	21	4	2
AMPHIPODA			
Hyaella azteca			11
Stygobromus	1		
ARHYNCHOBDELLIDA			
Erpobdellidae	-99		
BASOMMATOPHORA			
Ferrissia	13	7	6
Lymnaeidae	17	2	7
Physella			-99
COLEOPTERA			
Dubiraphia			28
Ectopria nervosa	1		
Macronychus glabratus			4
Optioservus sandersoni	8		
Peltodytes			1
Psephenus herricki	30	4	
Scirtidae			8
Stenelmis	51	41	4
DECAPODA			
Orconectes macrus	1	-99	-99
Orconectes neglectus			-99
DIPTERA			
Ablabesmyia		4	1
Axarus			1
Cardiocladius	10		
Ceratopogoninae		3	
Chironomidae			1
Constempellina			1
Corynoneura		2	
Cricotopus bicinctus		1	
Cricotopus sylvestris grp	2	2	
Cricotopus/Orthocladius	24	11	3
Cryptotendipes			1
Dicrotendipes		2	
Hemerodromia	9	1	9
Hexatoma	-99		
Labrundinia			10
Microtendipes		8	15
Nanocladius		2	2
Parakiefferiella		1	
Paratanytarsus		1	
Phaenopsectra		2	
Polypedilum flavum	10	2	
Polypedilum illinoense grp			2
Polypedilum scalaenum grp		3	
Rheocricotopus	2		
Rheotanytarsus	8	4	15

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15050], Station #6, Sample Date: 10/6/2015 11:15:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Simulium	5	1	
Stempellinella	12	38	13
Tabanus	1	1	
Tanytarsus	2	18	4
Thienemanniella	4	5	
Thienemannimyia grp.	1		2
EPHEMEROPTERA			
Acerpenna	9	3	
Anthopotamus	21	2	
Baetis	32		
Caenis anceps	44	41	3
Choroterpes		5	
Ephemera simulans	32	59	1
Heptageniidae	64	26	
Isonychia bicolor	8		-99
Leucrocuta	13	11	
Maccaffertium bednariki	4		
Maccaffertium mediopunctatum	58	5	1
Maccaffertium pulchellum	-99	3	1
Maccaffertium terminatum		1	
Paraleptophlebia	1	45	3
Procloeon		2	
Stenacron	14	58	
Tricorythodes	25	4	3
ISOPODA			
Caecidotea	1		
LUMBRICINA			
Lumbricina	-99		
MEGALOPTERA			
Corydalus	1	1	
Sialis		-99	
NEOTAENIOGLOSSA			
Hydrobiidae	5		
ODONATA			
Argia			1
Calopteryx			2
Enallagma	1	4	20
Hetaerina			47
Macromia			1
Stylogomphus albistylus		1	
PHARYNGOBDELLIDA			
Hirudinidae	-99		
PLECOPTERA			
Acroneuria	2	-99	
Agnetina flavescens	35	3	
Neoperla	15	2	
Perlinella ephyre		1	
TRICHOPTERA			
Ceratopsyche morosa grp	6		

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15050], Station #6, Sample Date: 10/6/2015 11:15:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Cheumatopsyche	49	12	
Chimarra	2		
Helicopsyche	3		
Hydroptila	1		
Marilia	1		
Oecetis		3	31
Polycentropus		2	2
Triaenodes	1	2	35
TRICLADIDA			
Planariidae	3	1	
TUBIFICIDA			
Tubificidae	2	7	
VENEROIDA			
Corbicula			-99
Pisidiidae	6	6	2

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15051], Station #5, Sample Date: 10/6/2015 12:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	25	4	5
AMPHIPODA			
Hyaella azteca			19
ARHYNCHOBDELLIDA			
Erpobdellidae		-99	
BASOMMATOPHORA			
Ferrissia	1	7	
Lymnaeidae	4	3	5
Menetus		2	
Physella			-99
COLEOPTERA			
Dubiraphia		34	29
Ectopria nervosa	1	3	
Optioservus sandersoni	25	4	3
Psephenus herricki	7	6	
Stenelmis	60	42	3
DECAPODA			
Orconectes macrus	-99	-99	
Orconectes neglectus	-99	-99	1
DIPTERA			
Ablabesmyia		9	4
Cardiocladius	13		1
Ceratopogoninae		3	
Chironomidae	1		
Chironomus		2	
Cladotanytarsus		6	
Corynoneura			2
Cricotopus sylvestris grp	11		5
Cricotopus/Orthocladius	27	2	8
Cryptochironomus	2		
Cryptotendipes		6	
Dicrotendipes		2	5
Hemerodromia			2
Hexatoma	1		
Labrundinia			14
Microtendipes	2	3	3
Paratanytarsus		2	
Paratendipes		1	
Phaenopsectra		1	1
Polypedilum flavum	14		8
Polypedilum halterale grp		2	
Polypedilum illinoense grp		1	2
Polypedilum tritum		1	
Rheocricotopus	1		
Rheotanytarsus	64	1	53
Simulium	2		
Stempellina			1
Stempellinella	10	13	1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15051], Station #5, Sample Date: 10/6/2015 12:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Tabanus	1	1	
Tanytarsus	13	39	18
Thienemanniella	5	2	
Thienemannimyia grp.	1	3	7
EPHEMEROPTERA			
Acerpenna	9		
Anthopotamus	70	9	
Baetis	39		
Caenis anceps	10	13	3
Caenis latipennis			5
Centropilum		4	
Choroterpes		6	
Ephemera simulans	8	3	
Heptageniidae	64		
Hexagenia limbata		2	-99
Isonychia bicolor	14		
Leucrocuta	9		
Maccaffertium bednariki	1		
Maccaffertium mediopunctatum	64	2	
Maccaffertium pulchellum	4	8	2
Paraleptophlebia	3	10	2
Procloeon		4	
Stenacron	28	14	
Stenonema femoratum		3	
Tricorythodes	38	2	16
HAPLOTAXIDA			
Haplotaxis	2		
LUMBRICINA			
Lumbricina	-99	1	
LUMBRICULIDA			
Lumbriculidae		1	
MEGALOPTERA			
Corydalus	1		
Sialis	1		
NEOTAENIOGLOSSA			
Hydrobiidae			-99
ODONATA			
Argia			8
Calopteryx			3
Coenagrionidae		1	
Enallagma			2
Erpetogomphus		2	
Hetaerina			3
Nasiaeschna pentacantha			-99
Stylogomphus albistylus	4		
PLECOPTERA			
Agnetina flavescens	26		
Neoperla	10	4	
TRICHOPTERA			

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15051], Station #5, Sample Date: 10/6/2015 12:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Ceratopsyche morosa grp	6		
Cheumatopsyche	63	2	
Helicopsyche	4		
Oecetis		1	13
Polycentropus			2
Triaenodes		1	45
TRICLADIDA			
Planariidae	3		
TUBIFICIDA			
Tubificidae	5	27	
VENEROIDA			
Corbicula	-99	2	
Pisidiidae	7	1	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15054], Station #4, Sample Date: 10/7/2015 11:05:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	38	2	
AMPHIPODA			
Hyaella azteca			1
BASOMMATOPHORA			
Ancyliidae	5	1	1
BRANCHIOBDELLIDA			
Branchiobdellida			1
COLEOPTERA			
Berosus		1	
Dubiraphia		27	43
Ectopria nervosa	1		
Macronychus glabratus		1	11
Optioservus sandersoni	7		
Psephenus herricki	4		
Scirtidae			2
Stenelmis	128	29	2
DECAPODA			
Orconectes macrus	-99		
Orconectes neglectus	-99		4
DIPTERA			
Ablabesmyia		16	
Cardiocladius	1		
Chironomidae		3	
Chironomus		2	
Cladotanytarsus		17	
Cricotopus bicinctus	2		
Cricotopus/Orthocladius	23	7	3
Cryptochironomus	2		
Cryptotendipes		1	
Dicrotendipes	1	9	
Epoicocladius		1	
Hemerodromia	1		14
Hexatoma	2		
Labrundinia			18
Microtendipes		1	
Nanocladius		1	
Parakiefferiella			1
Paratanytarsus			1
Phaenopsectra		2	
Polypedilum flavum	4		
Polypedilum illinoense grp	1		5
Polypedilum scalaenum grp	1	1	
Pseudochironomus		5	
Rheocricotopus			1
Rheotanytarsus	12		35
Simulium	1		3
Stempellina		1	
Stempellinella	26	36	1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15054], Station #4, Sample Date: 10/7/2015 11:05:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Stenochironomus			1
Stictochironomus		2	
Tanytarsus	17	35	7
Thienemanniella	1		
Thienemannimyia grp.	2		
Tipula			1
Tribelos			1
EPHEMEROPTERA			
Acentrella	2		
Acerpenna	3		
Anthopotamus	5	7	
Baetis	26		2
Caenis anceps	1		
Caenis latipennis		19	11
Centropilum		6	
Ephemera simulans	11	9	
Hexagenia		2	5
Isonychia bicolor	1		8
Leptophlebiidae		4	
Leucrocuta	5		
Maccaffertium bednariki	8		
Maccaffertium mediopunctatum	39	1	
Maccaffertium terminatum	71	4	21
Stenacron	16	4	1
Stenonema femoratum		2	
Tricorythodes	82	2	20
ISOPODA			
Lirceus			4
LUMBRICINA			
Lumbricina	1	-99	
MEGALOPTERA			
Corydalus	1		
Sialis		-99	
NEOTAENIOGLOSSA			
Elimia	8		
ODONATA			
Argia		1	18
Boyeria			1
Enallagma			9
Gomphidae	1	1	1
Hetaerina			8
Macromia		-99	1
PLECOPTERA			
Agnetina flavescens	27		
Neoperla	16		
TRICHOPTERA			
Cheumatopsyche	20		3
Helicopsyche	12	1	
Hydropsyche			3

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15054], Station #4, Sample Date: 10/7/2015 11:05:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Neureclipsis			1
Oecetis	1	1	30
Polycentropus			3
Triaenodes		2	19
TUBIFICIDA			
Branchiura sowerbyi		3	
Tubificidae	1	3	
VENEROIDA			
Corbicula	7	2	1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15053], Station #3, Sample Date: 10/7/2015 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	53	2	
AMPHIPODA			
Hyalella azteca			159
BASOMMATOPHORA			
Ferrissia		1	1
Lymnaeidae	6	1	
COLEOPTERA			
Berosus			2
Dubiraphia		14	33
Macronychus glabratus			3
Neoporus			1
Optioservus sandersoni	5	1	
Psephenus herricki	3	2	
Stenelmis	41	32	
DECAPODA			
Orconectes neglectus	-99		-99
DIPTERA			
Ablabesmyia		2	10
Antocha	2		
Cardiocladius	5		
Cladotanytarsus		6	2
Cricotopus bicinctus			3
Cricotopus/Orthocladius	22	9	16
Cryptochironomus		1	
Cryptotendipes		1	
Dicrotendipes		5	7
Hemerodromia	7		2
Labrundinia			2
Microtendipes	1	1	
Paracladopelma		1	
Parakiefferiella		1	6
Paralauterborniella		1	
Paratanytarsus			7
Phaenopsectra			2
Polypedilum flavum	4		
Polypedilum illinoense grp			1
Polypedilum scalaenum grp	1		
Procladius		1	
Pseudochironomus		4	
Rheocricotopus	1		
Rheotanytarsus	57	7	3
Simulium	5		
Stempellina		1	
Stempellinella	10	38	
Stenochironomus		2	
Stictochironomus		1	
Tabanus	2		
Tanytarsus	25	40	28

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15053], Station #3, Sample Date: 10/7/2015 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Thienemanniella		2	1
Thienemannimyia grp.		1	2
Tribelos		4	
EPHEMEROPTERA			
Acentrella	1		
Acerpenna	2		
Anthopotamus		2	
Baetis	25		
Caenis anceps	4	22	
Caenis latipennis			11
Centropilum		3	
Ephemera simulans	4	9	
Isonychia bicolor	33		
Leptophlebiidae		2	
Leucrocuta	3		
Maccaffertium mediopunctatum	23	2	
Maccaffertium pulchellum	43	19	
Maccaffertium terminatum	21		
Plauditus	2		
Stenacron	3	6	
Tricorythodes	115	23	2
ISOPODA			
Lirceus			1
LUMBRICINA			
Lumbricina	1	-99	
MEGALOPTERA			
Corydalus	3		
Sialis		-99	
ODONATA			
Argia	1	4	4
Enallagma			8
Gomphidae	1	2	
Hetaerina			1
Macromia			-99
PLECOPTERA			
Agneta flavescens	2		
Neoperla	17	4	
Perlesta	1	1	
TRICHOPTERA			
Ceratopsyche morosa grp	1		
Cheumatopsyche	58	2	
Helicopsyche	4	2	
Hydropsyche	1		
Hydroptila	1	1	
Oecetis	3	2	4
Polycentropus			21
Triaenodes			32
TRICLADIDA			
Planariidae	1		1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15053], Station #3, Sample Date: 10/7/2015 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
TUBIFICIDA			
Branchiura sowerbyi		3	
Tubificidae		1	
VENEROIDA			
Corbicula	-99	-99	
Pisidiidae	1	3	

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15052], Station #2, Sample Date: 10/6/2015 2:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	81	4	
AMPHIPODA			
Hyaella azteca			22
Stygobromus		1	
BRANCHIOBDELLIDA			
Branchiobdellida			2
COLEOPTERA			
Ancyronyx variegatus			1
Berosus		1	
Dubiraphia		1	26
Macronychus glabratus		1	4
Optioservus sandersoni	1	1	
Psephenus herricki	1		
Stenelmis	1	8	
DECAPODA			
Orconectes neglectus	-99		1
DIPTERA			
Ablabesmyia	1	6	4
Cardiocladius	9		1
Ceratopogoninae		1	
Chironomidae		3	1
Cladotanytarsus	2	136	4
Cricotopus sylvestris grp	6	4	
Cricotopus/Orthocladius	62	11	13
Cryptochironomus		2	
Dicrotendipes		3	1
Eukiefferiella brehmi grp		1	
Hemerodromia	5	1	1
Hydrobaenus		1	
Labrundinia		1	5
Paracladopelma		1	
Phaenopsectra		57	
Polypedilum flavum	2		
Polypedilum illinoense grp			1
Pseudochironomus		4	
Rheotanytarsus	5	3	9
Simulium	3		5
Stempellina		1	
Stempellinella	1	228	12
Tanytarsus	10	177	21
Thienemanniella	3	1	
Thienemannimyia grp.	1	4	2
Tipula	1		
Tribelos		6	
EPHEMEROPTERA			
Baetis	6		
Maccaffertium pulchellum	115	5	10
Plauditus	1		1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15052], Station #2, Sample Date: 10/6/2015 2:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Stenacron		1	
Tricorythodes	54	3	1
HEMIPTERA			
Rhagovelia	2		
ISOPODA			
Caecidotea (Blind & Unpigmented)	7	14	
LUMBRICINA			
Lumbricina	5	1	
MEGALOPTERA			
Corydalus	3		
ODONATA			
Argia	1	8	6
Boyeria			1
Enallagma			25
Erpetogomphus		12	
Hetaerina		-99	5
Macromia		2	3
PLECOPTERA			
Neoperla	2	2	
Perlodidae	1		
RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			
Cheumatopsyche	253		5
Helicopsyche	4	2	
Hydropsyche	3		4
Hydroptila		1	
Nectopsyche		11	
Oecetis	2	11	42
Polycentropus		1	30
Triaenodes		8	57
TRICLADIDA			
Planariidae	8		
VENEROIDA			
Pisidiidae			1

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15055], Station #1, Sample Date: 10/7/2015 2:00:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	70	2	
AMPHIPODA			
Hyaella azteca			86
COLEOPTERA			
Dubiraphia		1	1
Macronychus glabratus	1		1
Psephenus herricki		1	
Stenelmis	3	3	
DECAPODA			
Orconectes neglectus			-99
DIPTERA			
Ablabesmyia		4	3
Antocha	1	1	
Cardiocladius	24	1	1
Ceratopogoninae		4	
Chironomidae			2
Cladotanytarsus	6	73	4
Cricotopus bicinctus	1	6	
Cricotopus/Orthocladius	39	21	5
Cryptochironomus		3	
Dicrotendipes		30	2
Hemerodromia	3	1	
Labrundinia			3
Parakiefferiella			1
Paratanytarsus		1	1
Phaenopsectra		2	1
Polypedilum flavum	1		
Polypedilum illinoense grp		1	
Polypedilum scalaenum grp		9	1
Pseudochironomus	2	43	5
Rheotanytarsus	27	1	7
Simulium	3		
Stempellinella	8	28	8
Tabanus	-99	-99	
Tanytarsus	12	34	36
Thienemanniella	3		
Thienemannimyia grp.		2	1
Tipula		1	
Tribelos		18	
EPHEMEROPTERA			
Baetis	3		
Caenis anceps	2		
Caenis latipennis	1	20	11
Maccaffertium pulchellum	107		6
Maccaffertium terminatum	1		
Plauditus	55		
Stenacron	1		1
Tricorythodes	198	32	5

Aquid Invertebrate Database Bench Sheet Report**Center Cr [15055], Station #1, Sample Date: 10/7/2015 2:00:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
HEMIPTERA			
Mesovelina			1
ISOPODA			
Lirceus			4
LEPIDOPTERA			
Petrophila	1	1	
LUMBRICINA			
Lumbricina	1	-99	
MEGALOPTERA			
Corydalus	3		-99
ODONATA			
Argia	1	2	11
Enallagma			4
Erpetogomphus		3	
Hetaerina			5
Macromia		-99	1
Neurocordulia			-99
TRICHOPTERA			
Cheumatopsyche	157	1	1
Chimarra	1		
Helicopsyche	2		
Hydropsyche	24	1	1
Hydroptila	2	2	1
Nectopsyche		6	
Oecetis		5	17
Polycentropus	2		28
Psychomyia	4	1	
Triaenodes		1	31
TRICLADIDA			
Planariidae	3		
TUBIFICIDA			
Quistadrilus multisetosus		1	
VENEROIDA			
Pisidiidae	1		1